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MIT's Magazine of Innovation

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BROWSE THE EARTH

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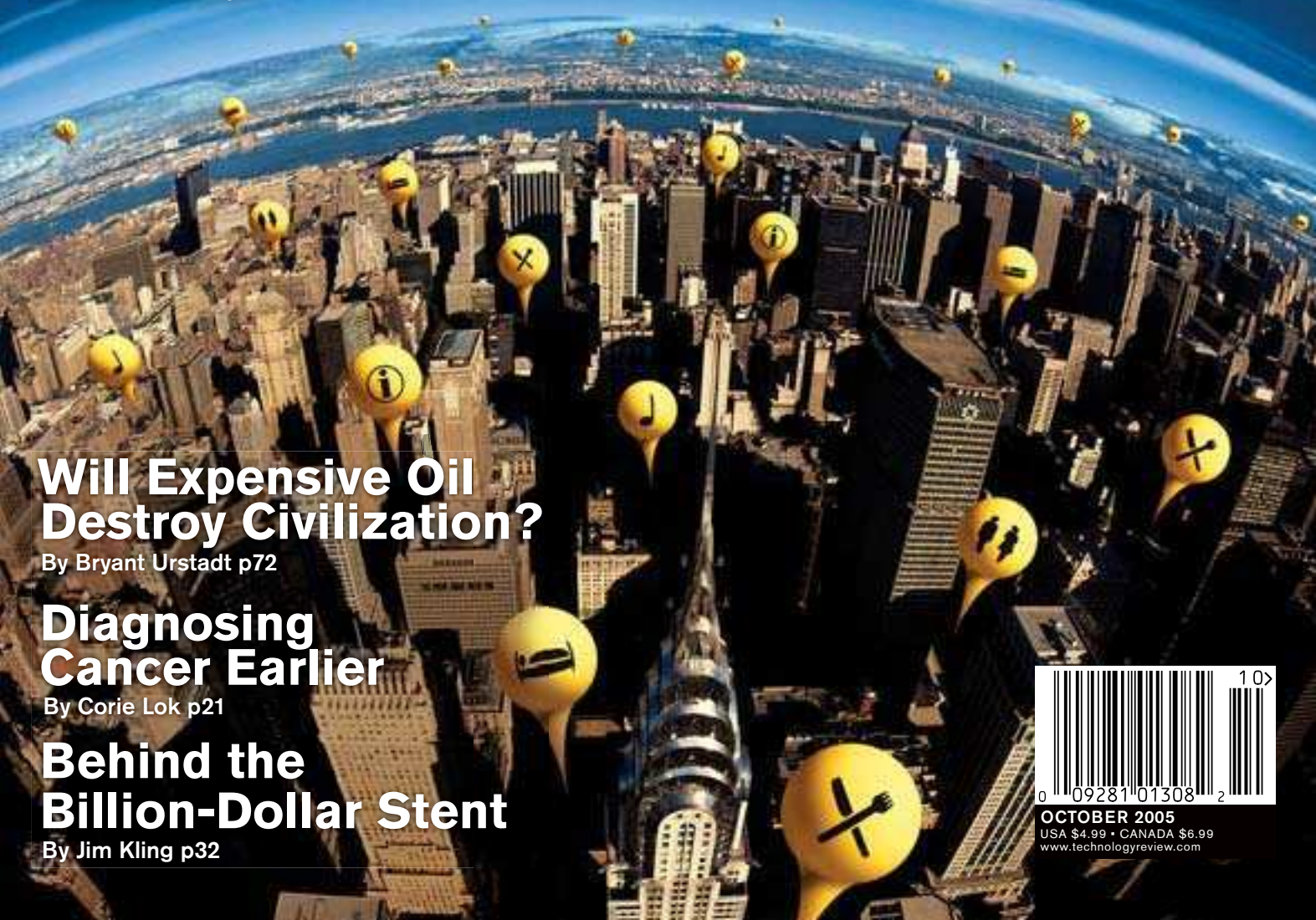

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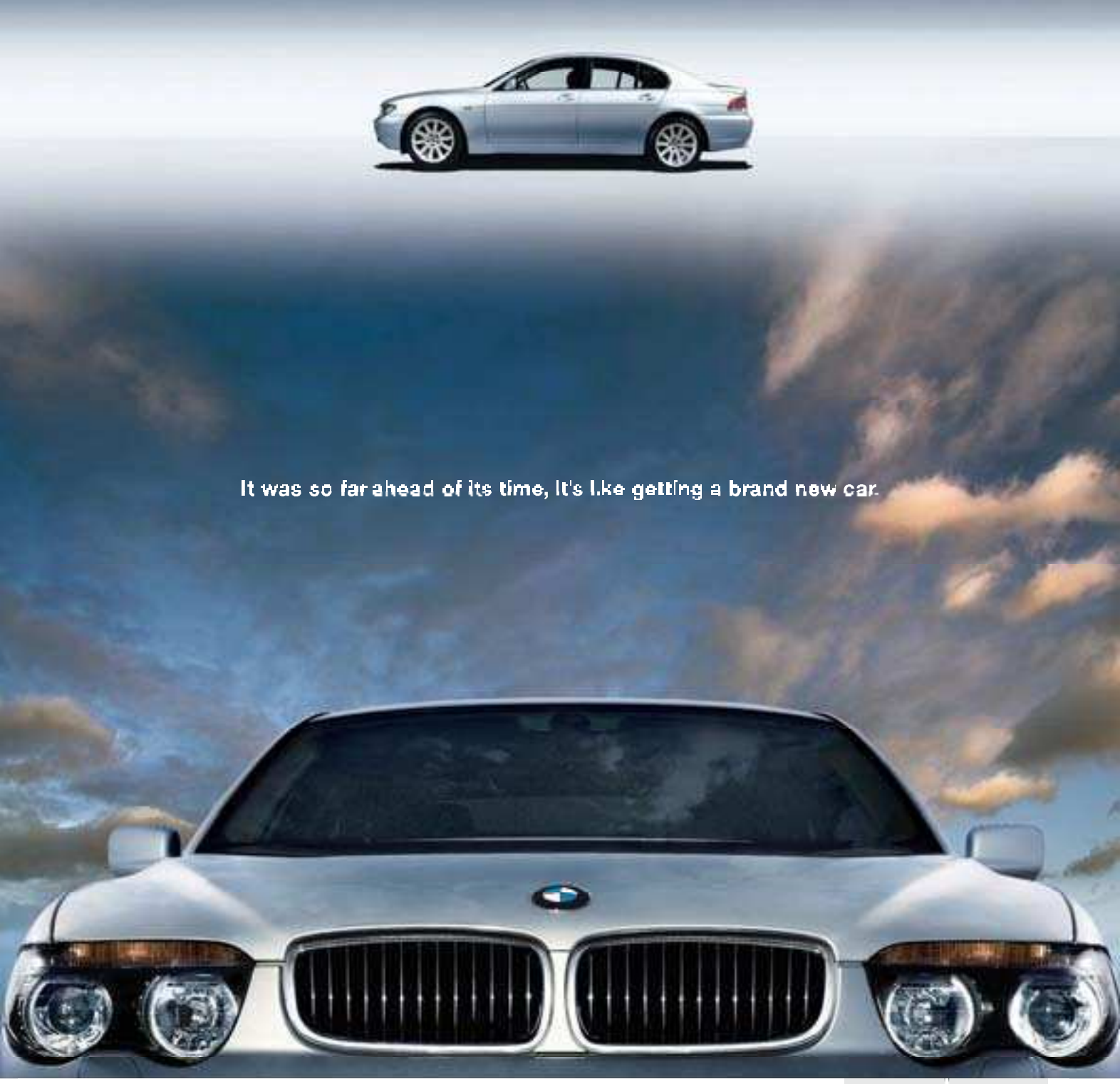

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Certified Pre-Owned

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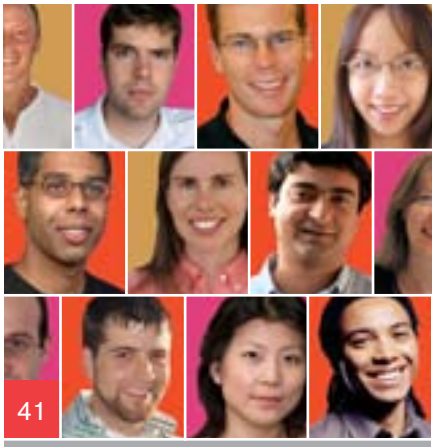

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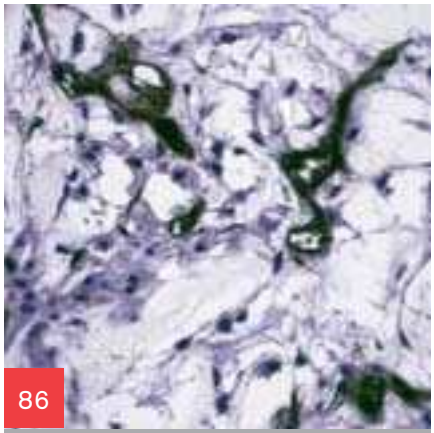

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FROM MIT'S LABS
Engineering Muscle Tissue
A new technique allows blood vessels to be grown in muscle before implantation.

What's new at technologyreview.com

This month at technologyreview.com, we're helping everyone get a much better view of their world.

Online mapping tools are getting an upgrade. For this month's cover story (see "Killer Maps," p. 54), *Technology Review* senior editor Wade Roush describes the new views of the Earth—and of human culture—that are becoming available thanks to the work of independent software developers and big companies such as Microsoft, Yahoo, and Google. At www.technologyreview.com/maps, Roush takes readers on a tour of the coolest new online mapping applications, from Microsoft's MSN Virtual Earth to map "mash-ups" such as HousingMaps.com.

This issue of the magazine reveals the TR35, our list of the top innovators under 35. We've created an online interface that will let you easily find your way through the list. And we've reserved two special winners—Technology Humanitarian of the Year and Innovator of the Year—to be revealed at our Emerging Technologies Conference at MIT on September 28.

About Technology Review *Technology Review*, the oldest technology magazine in the world, is published by Technology Review, Inc., an independent media company owned by the Massachusetts Institute of Technology. Founded in 1899, *Technology Review* describes emerging technologies and analyzes their commercial, economic, social, and political impact for an audience of senior executives, researchers, financiers, and policymakers, as well as for the MIT alumni. In addition, Technology Review, Inc. produces technologyreview.com, a website that offers daily news and opinion on emerging technologies. It also produces live events such as the Emerging Technologies Conference. The views expressed in *Technology Review* are not necessarily those of MIT.

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Bryant Urstadt wrote this month's review of James Howard Kunstler's *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century*, which argues that the coming end of cheap oil will threaten civilization as we know it (see "The Get-Ready Men," p. 72). "It is one of those great books," says Urstadt, "that tries to change your worldview. After I'd finished it, I was pretty much ready to head to the country with a bag of seed. Looking deeper, there was more to it, but it's a book that can really scare people. That may not be a terrible thing." Urstadt is a freelance writer whose work has appeared in *Harper's*, *Rolling Stone*, and the *New Yorker*.

Senior editor **Wade Roush** wrote this month's cover story on the way location-specific information is fundamentally changing the Web (see "Killer Maps," p. 54). "While I was researching and writing about the new movement in geo-aware computing," he says, "I found that I was experiencing 'place' in a different way myself. I'd just gotten a GPS receiver, I was paying a lot more attention to online mapping tools, and I was hanging around geeks who were linking places on the map with places on the Web. I started to feel like places on Earth could also become repositories, for my memories and those of everyone else who had passed through them. Now those places can hold memories of us online. I don't know exactly how that's going to change our lives, but it definitely will."

Michael Fitzgerald accepted our invitation to review a new wireless-networking technology called MIMO (multiple input, multiple output) (see "Hearing Multiple Signals," p. 77). He reports that upon receiving a router equipped with the technology, his first thought was, "Hey, maybe this thing gives me a reason to buy one of those new TVs with Wi-Fi!" But, he says, "I soon found that the answer is, Not yet. But I would like to be able to zip things from the DVR upstairs to the big-screen TV in the rec room, or take the TV into the confines of my office during the Stanley Cup play-offs." Fitzgerald is a reporter and editor who has worked at TechTV, *Red Herring*, and *Computerworld*. His writing has appeared in *Inc.*, the New York *Times*, and the *Economist*.

Steve Brodner created the illustration of a pizza-baking cell phone and other prospective PDAs that appears on the last page of this issue. "Cell phones have changed our lives—for the better, mostly, I think. At least I felt that way when I was rear-ended on the Cross County Expressway last January and the police arrived in about four minutes," says Brodner. "Now, in their unending quest to get consumers to replace everything they've already bought, companies are combining many gizmos into a single device. My cartoon explores the possible next steps." Brodner is a caricaturist whose work has appeared in many major publications. A book of his collected work, *Freedom Fries*, was published last year.

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Technology and Hypercuisine

One evening late this summer, I dined at Charlie Palmer's Dry Creek Kitchen, a restaurant attached to the Hotel Healdsburg in Sonoma County, CA. My dinner companion was my oldest friend, Circe Sher, whose family owns the hotel. We plowed through a six-course meal whose menu, when we read it, seemed conventionally eclectic in its influences and very Northern Californian in its emphasis on local ingredients.

We ate a tomato consommé with a yellow tomato sorbet; *branzino*, a form of Mediterranean sea bass, stuffed with truffles and wrapped in bacon; squab with chanterelle mushrooms on a bed of *foie gras*; cumin-infused lamb; beef prepared two different ways and presented with a variety of vegetables; and, for dessert, a peach *tarte tatin*.

But a mere transcription of the menu cannot suggest the strangeness of the food. The squab was like nothing I had eaten before: every mouthful tasted overpoweringly of *squabbishness*, and the texture of the bird's flesh, while not unpleasant, was oddly silky. By the time I had finished the lamb, I knew something was up. It was evenly cooked throughout and tongue-staggeringly gamy in its intensity, and, once again, the texture was weirdly succulent—more like a fruit or liquescent vegetable than meat.

"That's Michael, the new chef," Circe explained smugly. She had anticipated my bewilderment. "He's really into *sous vide*."

Michael Voltaggio, the *chef de cuisine* at Dry Creek Kitchen, is a proponent of a newly fashionable style of cooking that is sometimes described as "scientific" cooking or, more Gallically, "hypermodern" cuisine. It is aggressively technological: it borrows techniques from industrial food preparation and applies them to fine dining. *Sous vide* (in French, "under vacuum") is its most remarkable and best-known innovation. Ingredients are put into plastic bags and vacuum-packed (a process called Cryovacking) and then cooked in warm water at low temperatures for very long periods.

Backstage, Voltaggio's kitchen was more like a laboratory than most kitchens of my experience: quieter, neater, and less anarchic. The chef, an austerely thin, red-haired young man, showed off his Cryovac. It looked like nothing much, although such machines can cost thousands of dollars. Next to it was a stainless-steel thermal circulator, or water bath, whose temperatures could be adjusted to within a tenth of a degree.

Briskly, Voltaggio explained the benefits of *sous vide*. High temperatures damage food, he says, causing the cell walls of meat, fish, and vegetables to burst; the damaged food cannot reabsorb the juices it exudes as it cooks. By contrast, Voltaggio says, the low temperature range of *sous vide* cooking cossets food and creates very little exudation; and the hermetic seal of the vacuum pack permits what is exuded to be reabsorbed.

I asked Voltaggio how he had achieved his very tasty but strangely glutinous lamb. "I cured it for 10 hours in salt and rosemary. Then I Cryovacked it with the cumin and cooked it at 58 degrees Celsius for 36 hours."

For gourmands, the person most associated with the application of technology to food is Ferran Adrià of El Bulli, in Spain. But the individuals really responsible for *sous vide* are a French food scientist named Bruno Goussault (recently the subject of an admiring profile by Amanda Hesser in the New York *Times* magazine) and his sometime collaborator, sometime rival, the French chef Georges Pralus.

While the enthusiasm for hypercuisine is new, the methods developed by Goussault and Pralus are not. Vacuum-packing has been used by food companies while pasteurizing foods since at least the 1960s, but the temperatures initially employed were very high. Starting in the mid-1970s, Goussault and Pralus, working with the Cryovac division of the W. R. Grace Company, explored ways to cook "under vacuum" at lower temperatures. Goussault discovered that low temperatures were sufficient to cook foods so that they could be safely eaten. At first, the technique was used on an industrial scale by hotel chains, airlines, and railways; but it has gradually been adopted by younger chefs like Adrià and Voltaggio (although it should be noted that the latter cook also prepares other dishes by more traditional means).

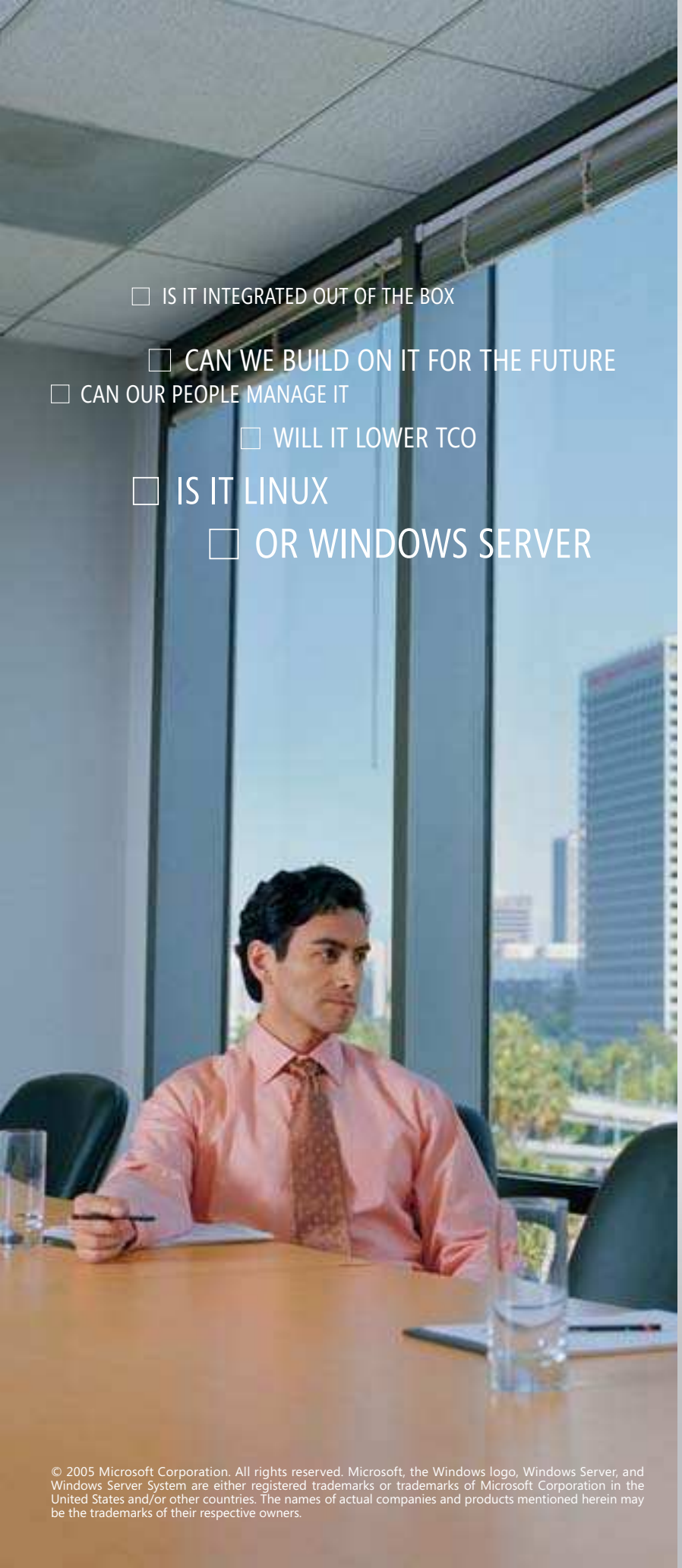
Hypercuisine is aggressively technological: it borrows techniques from industrial food preparation and applies them to fine dining.

Sous vide is only one of the techniques seized upon by the practitioners of hypercuisine. Everywhere, chefs are consciously altering the chemical structures of proteins, starches, and fats to produce hitherto untasted flavors and textures. They are flash-freezing sauces, emulsifying weird combinations of oils and juices, and beating vegetable broths into airy froths. For casual diners like me, the experience of eating such meals can be unsettling: it's delicious, but it is also food created not so much to nourish as to entertain.

This is deliberate. The practitioners of hypercuisine represent a kind of insurgency against the ideals of good food that have dominated restaurants for the past 25 years. Those ideals, first championed by Alice Waters at Chez Panisse in Berkeley, CA, emphasized the use of fresh, seasonal foods that were simply but perfectly prepared.

"But chefs and diners got bored," Voltaggio argues. "Now that people can buy restaurant-quality grills and ovens, anyone can braise veal cheeks. I want people to ask, 'How did he *do* that?'"

If you haven't eaten hypercuisine, you will soon. Do you think fine food should be a kind of higher game? Write and tell me at jason.pontin@technologyreview.com. ■



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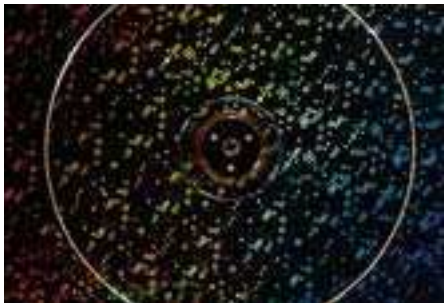

The Hundred-Dollar Laptop

I read with great interest your article on the Hundred-Dollar Laptop, or HDL, proposed by MIT Media Lab founder Nicholas Negroponte ("From the Editor," August 2005). I have been living in Haiti for the last two decades and, as a member of the Haitian Association of Technology Entrepreneurs, I have looked for years to find ways to increase poor people's access to new technologies.

The success of an HDL will depend on the availability of new third-party software. For example, we are developing a multimedia application that uses the Creole language and a tactile screen to help illiterate people use a computer; we could very well try to integrate such an application in an HDL. Another important factor will be the ability to manufacture such a machine locally, using inexpensive components. I am ready to concretely explore those options here in Haiti.

Patrick Attié
Petionville, Haiti

While an HDL would be a boon to our world, simply making the Internet available to the masses is a far cry from actually educating them. I worked with my children's local school district through two technology tax levies to help ensure that money wasn't thrown at a problem without a plan to use it intelligently. Getting information to the children is only a part of the solution. Providing guidance and structure to learning is every bit as important, if not more important. Providing teachers with education on how to use the technology for teaching was and is as important as providing the computers and Internet access. Also, will providing the technology instruction actually prepare these youth for the world that they live in?

Keith L. Breinholt
Duvall, WA

It's more important to address the issue of content analysis than of offering inexpensive laptop computers. What good is the Internet for kids who can barely read, and therefore can't discriminate between authoritative information and trash? Without such discernment, all this effort will be lost to chat rooms, porn, and games. I'm Mexican, and I've seen which sites Mexican kids surf in cybercafés—and it's not ones like Project Gutenberg.

Rosina Bucio
Basel, Switzerland

I congratulate Nicholas Negroponte for his Hundred-Dollar Laptop idea and hope he will be able to make a good business case for it. In the end, however, the key factor will not be the computer itself but the software that it runs. How will this software enhance the educational capabilities of the user, reflect local cultural norms, and be integrated into schools?

Marcel Bullinga
Amsterdam, The Netherlands

The HDL has already been built for much less than a hundred dollars; let's call it the LTHDM (Less-Than-Hundred-Dollar Machine). Yes—I'm talking about your old desktop computer. There are millions of LTHDM units waiting to be used. Instead of offering poor children new machines that have not been field-tested, let's ship them our old machines, loaded with a Linux operating system. I just don't get why we have to build new machines when we already have millions to spare.

Saad Kadhi
Paris, France

Nicholas Negroponte responds:
The reuse of old desktop computers is a fine idea, and one that I encourage, but for three reasons does not obviate the need for laptops for children. First, if a child is to have a seamless learning experience, she needs a device that travels with her. Second, if we assume that there are 100 million desktops available, and that each unit requires only one hour of human attention to be refurbished, getting those desktops to the people who need them will require 45,000 work years. Third, children in the developing world need the newest technology to provide really rugged hardware and innovative software.

Genomic Diet

Corby Kummer's article, "Your Genomic Diet" (August 2005), did a superb job of distilling this exciting post-genomic technology into terms that nonspecialists could understand. I wanted to point out, though, that lunasin is a protein component of soybeans and not, as you report, an isoflavone, which is a small-molecule metabolite. Both of these components of soy, however, reduce cancer risks in cell culture, small laboratory animals, and humans. Despite this error, Kummer's message is a good one: your genetic profile could be the key to knowing what to eat.

Alfredo Galvez
Davis, CA

Casino-Friendly Technology

Your article on blackjack sensors ("The Digital Pit Boss," August 2005) neglects to mention a huge advantage that this technology would confer on the casino by enabling it to efficiently spot card counters —players who track expended cards and adjust their bets depending on whether the remaining deck is "rich" or "poor" in critical aces and tens. A good card counter can tip the house's .45 percent advantage to a player advantage of between .25 and .50 percent. Giving the casino the power to track betting patterns will put the truly skilled player out of business.

Sean Sebastian
Pittsburgh, PA

Abused Substances

I enjoyed "Abused Substances" (August 2005) in defense of the drug Ecstasy. MIT's Jerome Lettvin should pen a rebuttal! He thrashed Dr. Timothy Leary on the subject of LSD in their famous 1967 debate at MIT. Now that was a trip!

Barney C. Black
Falls Church, VA

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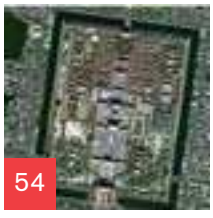
Geography Goes Online



Online maps date to the early days of the Web, and accurate signals from the Global Positioning System have been available to consumers for half a decade. But until just recently, there wasn't much overlap between these technologies: very little of the information on the Web was keyed to specific geographic coördinates, and anyway, few people carried the location-aware devices that could retrieve such information. But that's beginning to change: an increasing number of wireless Internet-connected devices have built-in GPS and other location-finding technologies, and—just as important—the Web itself is being restructured to complement the actual geography around us.

That means that long-touted visions of "location-based services" are coming to life, but with a populist twist. Yes, the café you pass on your way to work every morning will be able to send a coupon to your cell phone, if you opt to receive such offers. And search-industry heavyweights Google, Yahoo, and Microsoft are building nifty new platforms that organize local search results—and, of course, advertisements—according to geographic location. But at the same time, as we explain in "Killer Maps" on page 54, average Web users can now upload their own geographically tagged content to the Web. This allows other users to download content that is pertinent to wherever they happen to be at a given moment. This ongoing "annotation of the planet," to use technology columnist John Udell's felicitous phrase, has the potential to deepen everyone's experience of place.

If you have a GPS-enabled camera phone, for example, it can automatically tag your photos with the latitude and longitude of the location at which they were taken and upload them to a website where they'll appear in the appropriate positions on a map. And that's only the beginning: Web developers are using the new mapping platforms and emerging standards to "geotag" Web pages, creating entirely new location-based social and political forums, artworks, games, and community knowledge banks. It's one of the most advanced examples of what, in a recent issue, we called "continuous computing": the far more extensive, yet less obtrusive, way in which information technology is beginning to permeate our daily lives, thanks to advances in mobile devices, wireless networking, and Web development standards. Mapmaking, once the exclusive realm of cartographers, is now part of that permeation—and it is taking its overdue place alongside other forms of digital mass communication. ■

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INNOVATION

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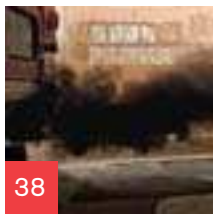
The TR35 points to the globalization of talent.

A reader poring over the profiles of this year's TR35 *(p. 41)*, *Technology Review*'s annual pick of the world's top innovators under the age of 35, might be forgiven for humming a few bars of "The Star-Spangled Banner." We pushed hard for nominations from all over the world, but in the end, the best judgment of the editors and our team of esteemed judges produced a list of 35 people that includes 33 working at U.S. companies or universities. But this seeming American hegemony is illusory. Well over a third of this year's TR35 are originally from other countries, including China, India, and Singapore.

A pattern emerges from the dossiers of these extraordinary people: a brilliant young scientist or engineer receives a degree in his or her native country and then emigrates to take advantage of the superior graduate schools and richer entrepreneurial opportunities in the United States. But that situation will not necessarily persist. In its latest survey, the Council of Graduate Schools—a Washington, DC–based consortium of more than 450 institutions—reports that in 2005, international graduate applications to U.S. schools are down 5 percent from the previous year, with a particular drop-off in students from China (down 13 percent) and India (down 9 percent). This follows similar declines in recent years. The reasons behind these numbers are not totally clear. But surely one factor is that the growing economies of China and India are increasingly providing ample opportunities, both in academia and business, for those who stay home.

In the long run, this inevitable outcome of globalization might spur more innovation worldwide. But it is not good news for the United States. As this year's TR35 remind us, the United States' ability to draw extraordinary talent from around the world feeds a rich climate of innovation and scientific advancement that everyone in this country benefits from. ■



ENVIRONMENT

Regulation Works

And must, if we want things like clean air.

As Charles Fishman reports in our "One Decision" Briefcase *(see "Cleaning Up," p. 38)*, Corning is investing heavily in diesel-filtration technology. In the teeth of the most recent recession, Corning dedicated itself to spending half a billion dollars on this technology—even as it cut its overall R&D budget by half.

Regulations being implemented around the world spurred Corning's decision. In the United States, the Environmental Protection Agency will require that heavy-duty diesel trucks and buses made for model year 2007 use fuels that contain 97 percent less sulfur than is currently found in diesel fuel. The kind of filtration that Corning is developing will also be mandated for trucks and buses beginning in 2007 and for nonroad engines beginning in 2011. Three decades ago, in response to the Clean Air Act of 1970, the company invented the ceramic material used in catalytic converters. It has led that business ever since. Corning sees an opportunity to do for diesel engines what it did for gasoline engines: it expects that, beginning in 2008, diesel emissions mitigation will be a billion-dollar-a-year market.

There's a basic economics lesson in this. Free markets generate "externalities"—costs that neither the buyer nor the seller in a transaction will bear, and benefits that neither will enjoy. Air pollution is a textbook example of a negative externality: the bicyclist bears the cost of a driver's exhaust.

Some negative externalities have no easy remedy. But in cases where the private sector can, given enough incentive, develop a technological fix, the solution is clear: the government must mandate the removal or reduction of the externality. Companies like Corning will take it from there. ■

ENERGY

Solutions Scenario

The exhaustion of cheap oil will not be catastrophic.

Conversations among energy wonks can remind listeners of the adage about the half-full glass. Pessimists think that oil production will peak sometime in this decade; optimists believe that new technologies could extract untapped oil reserves for at least a few decades more. But there is one thing no one disputes: we will soon run out of cheap oil.

A growing, influential body of writers believes that the exhaustion of cheap oil will be disastrous. On page 72 of this issue, we take a look at *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century*, by James Howard Kunstler. The author, a novelist and journalist who has written for the *Atlantic* and *Rolling Stone*, writes that we will fall into "an abyss of economic and social disorder on a scale that no one has seen before." Are he and his fellow doomsayers right?

Hardly. To agree with Kunstler is to believe that alternative sources of energy cannot replace oil. This means dismissing the combined powers of natural gas, solar power, wind, coal, hydroelectric, biomass, and nuclear power. Doomsayers argue that these alternatives are a "mirage," as Kunstler puts it, because they will never produce as much energy as cheaply as oil. But that assumes we will not devise ways to use energy more efficiently. It also ignores the rapid progress in improving energy technologies, particularly in solar, wind, and nuclear power.

We have faith in human ingenuity: as oil prices increase, technologists will find new ways to generate energy. ■

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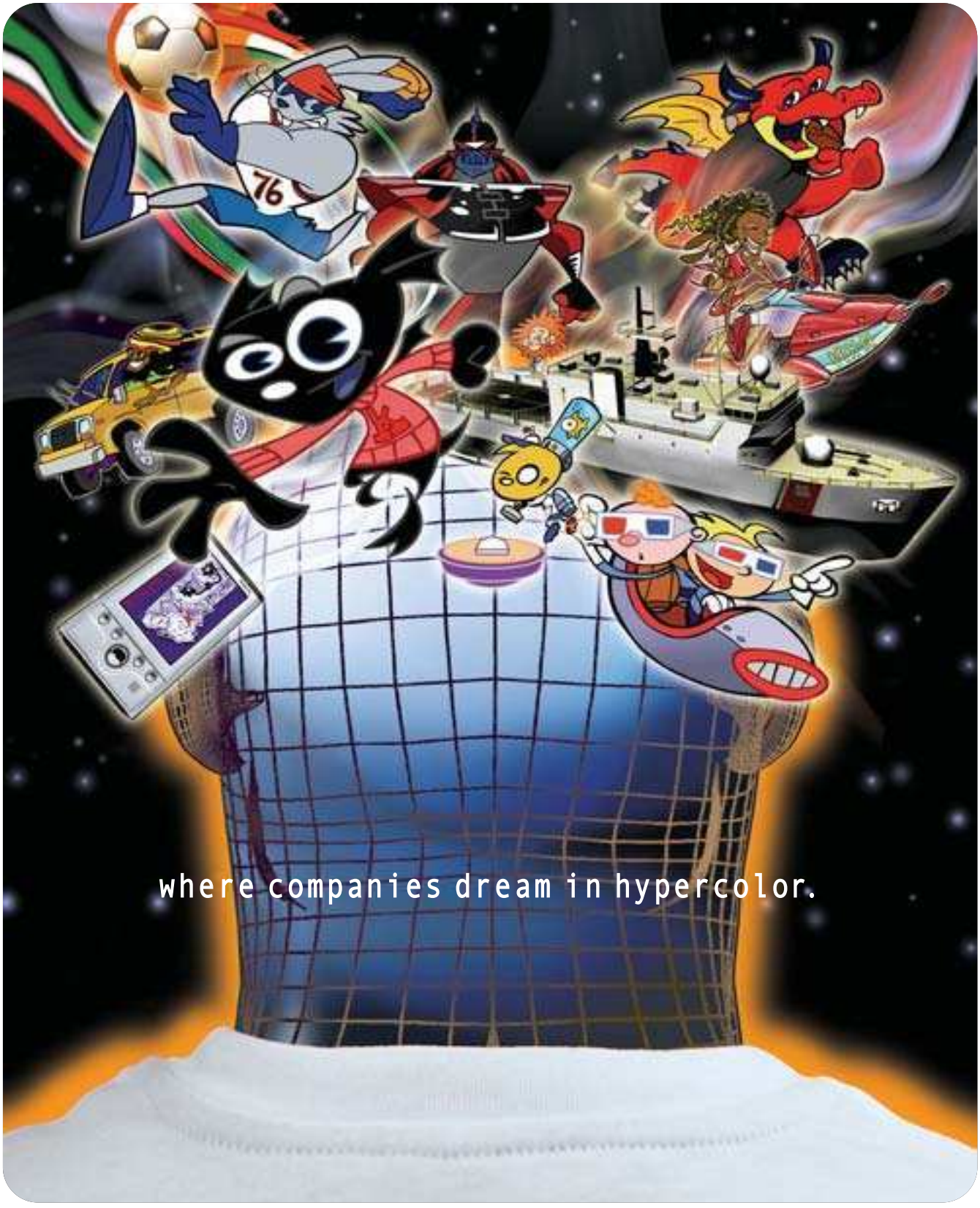

Business is busting at the seams for Orlando's digital media sector. Home to top-notch studios like Electronic Arts, specialized higher-ed training programs, and the world's largest concentration of simulation developers, it's no wonder companies around here are so animated.

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Forward

Voices

"When you go to a market leader with a disruptive technology, most of the time, they aren't interested."

Bill Hunter, cofounder and CEO of Angiotech Pharmaceuticals, p. 33

"Suddenly, the very people who are victims are empowered to bear witness to the world almost instantaneously."

Andy Carvin, director of the Digital Divide Network, on the effects of mobcasting, p. 44

"Maps are increasingly a 'read-write' medium. That changes how we interact with them and the impact they can have on our everyday lives."

Schuyler Erle, chief engineer at Locative Technologies and coauthor of *Mapping Hacks*, p. 57

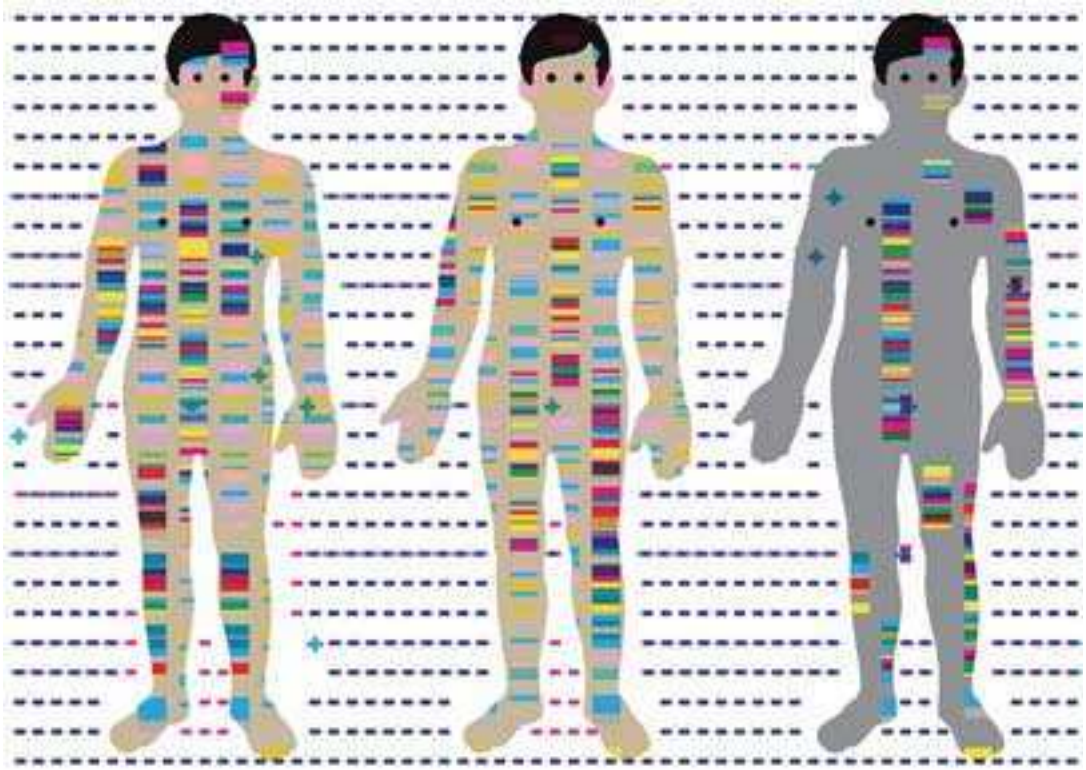
BIOTECH

Better Cancer Detection

New tests could catch the disease earlier

MANY OF TODAY'S tools for screening and diagnosing cancer are crude at best. So researchers are working to find more-sensitive tests based on specific molecules—called "biomarkers"—that are early signs of tumors and whose concentration could, ideally, be measured in bodily fluids like blood. While much of that research has focused on protein biomarkers, some of the first molecular tests to arrive on the market may be ones that look instead at a phenomenon called DNA methylation. A few small biotech companies, some partnered with major pharmaceutical companies like Johnson and Johnson and Roche, say their first DNA methylation–based tests for prostate cancer could be available next year.

DNA methylation occurs when methyl groups—carbon atoms surrounded by three hydrogen atoms each—attach to a gene without changing its actual sequence. Methyla-



JOE MAGEE

tion can alter a gene's behavior by, for instance, turning it off, and aberrant patterns of methylation are involved in almost all types of cancer. What's more, abnormal methylation happens early on in the disease process, which makes it "a highly promising biomarker for cancer," says Stephen Baylin, an oncology professor at the Johns Hopkins School of Medicine. Researchers have so far identified some 40 to 50 genes whose methylation patterns play a role in the development of cancer.

One of the leading companies in the development of methylation-based cancer tests is OncoMethylome Sciences of Liège, Belgium. It is collaborating with Johnson and Johnson to develop a prostate cancer diagnosis test, which it is currently testing on a few hundred patients in six U.S. medical centers. The test, which OncoMethylome expects to commercialize by next year, would detect methylation in biopsied prostate tissue. The current method of diagnosis—examination of the tissue under a microscope—misses up to 30 percent of cancers, so the new test would be used to confirm that cancer really was absent in biopsies that appeared normal.

Microscopic examination of prostate tissue misses up to 30 percent of cancers. A new test could confirm that seemingly normal tissue was really cancer-free.

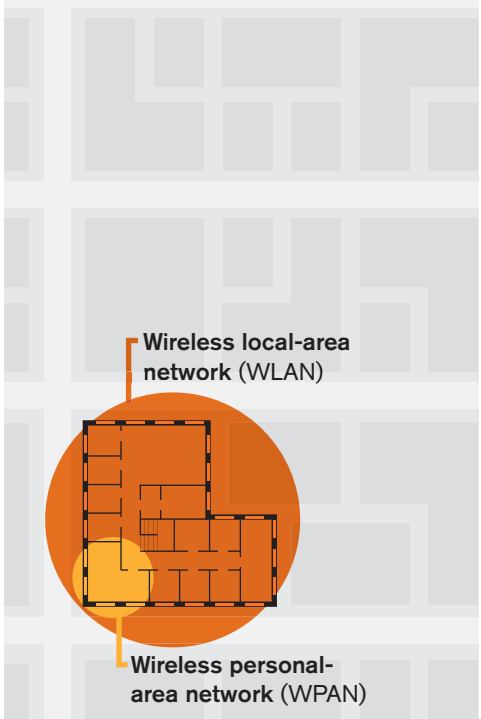
OncoMethylome is developing another set of tests to screen patients for cancer before they reach the stage where a biopsy is called for. These screening tests would look at patterns of methylation in two to five genes from DNA in blood, urine, or saliva. The tests, which won't be available for at least another two years, are designed to detect early signs of cancers of the ovary, bladder, prostate, and lung. Competing company Epigenomics of Berlin, Germany, has partnered with Roche to develop similar blood tests for prostate, breast, and colon cancer, and it expects them to reach market by 2009.

Like most other screening tools, these bodily-fluid tests will likely not offer definitive results; positive tests would still need to be confirmed. However, DNA-methylation screening is designed to be highly accurate in identifying the people who really *don't* have cancer so that they won't needlessly undergo more invasive and expensive testing such as colonoscopy. Still, the tests will first need to be fast and cheap enough for routine use in hospitals and diagnostic labs. **Corie Lok**

TELECOM

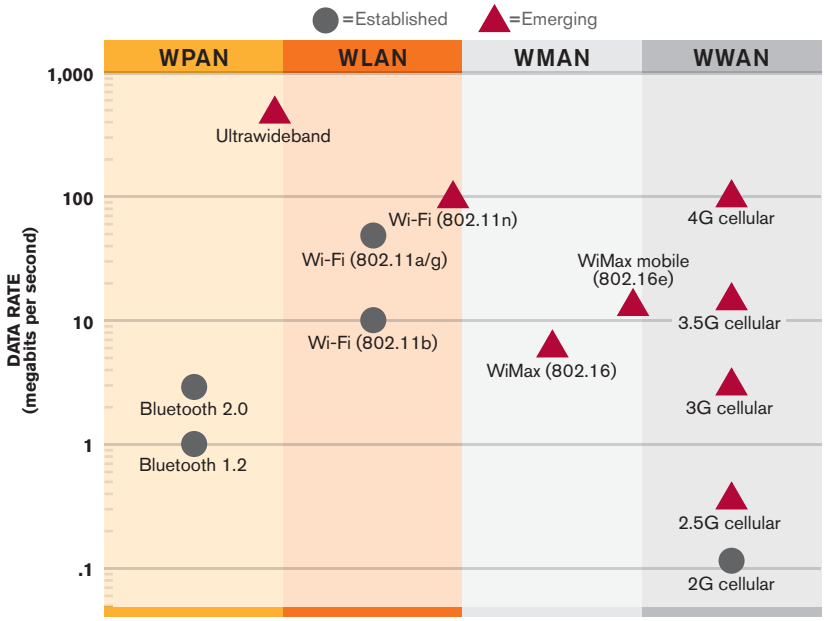
Online Everywhere

New wireless technologies due to become available in the coming months promise blazingly fast Internet connections at home and on the go. Here's what we have now and what we have to look forward to.



How new technologies stack up

Actual performance will vary depending on factors such as how the technology is deployed, the user's distance from base stations, and interference.



SOURCES: IEEE, GSM ASSOCIATION, WIMEDIA ALLIANCE, BLUETOOTH SIG, CDMA DEVELOPMENT GROUP, NTT DOCOMO, UMTS FORUM, FARPOINT GROUP, ERICSSON, WIMAX FORUM

BIOTECH

Bio Programming

Juan Enriquez's company creates new organisms

The next step after reading genetic code is writing it. In June, biotech pioneers J. Craig Venter and Hamilton Smith launched Synthetic Genomics, a Rockville, MD–based "synthetic biology" startup aimed at creating custom-made microörganisms. The new company's president is Juan Enriquez, former director of Harvard Business School's Life Sciences Project and CEO of the Wellesley, MA, investment partnership Biotechonomy, which funds Synthetic Genomics.

How is what you're doing different from conventional genetic engineering?
Genetic engineering mostly has been about taking a few genes, shooting them at random at cells, and seeing if anything sticks. What we're doing is very different—synthesizing entirely new DNA strands with the aim of controlling a particular life function. We then insert those into cells and have them execute that function.

What kinds of functions?
We've made a decision to focus on big problems with global impact, initially energy and global warming. Specifically, we're looking at how to optimize microörganisms that generate ethanol and hydrogen. But there's potential application for any carbon-based industry, including chemicals, carbon sequestration, and pollution remediation. To the extent that you can program how individual cells function, you can change global industries on a very large scale.

Even so, critics will take one look and say, "Frankencells!"
We're working to look at the ethical issues. You don't want to put something on the market and then have people start asking all these questions. One way of looking at this is it's the next stage in the Green Revolution. Or alternatively it's the next stage of the Industrial Revolution. I think it's both.

How does Synthetic Genomics plan to make money?
We're not trying to take over the world. We're a bleeding-edge technology company that will make its money by licensing. But I expect you'll see us announcing partnerships with some very large companies. **Spencer Reiss**

COURTESY OF VTT (GROCERY PHONE); DANA SMITH (BIO PROGRAMMING)

Prototype

Motion pictures

You're looking at a photo of some van Gogh sunflowers, and the flowers start to sway on their long stalks as if stirred by a breeze. No, it's not an LSD flashback; it's the product of new image-editing tools developed at the University of Washington and Microsoft. With the tools, a user can divide a digital still image into layers and assign a different action to each layer. In a photograph of a sailboat, for example, a swaying motion could be applied to the boat and a sideways motion to the clouds; the water, meanwhile, could be animated by algorithms that produce small distortions resembling ripples. The result can be played in a digital picture frame or as a desktop background or screensaver on a PC. The tools are experimental but might eventually be included in products, says lead researcher Richard Szeliski.

Grocery phone

A system being developed in Finland turns camera-equipped cell phones into personal health and fitness advisors. A supermarket shopper using the technology can snap an image of the bar code on a packet of food. The phone forwards the code number to a central computer, which sends back information on the item's ingredients and nutritional value. The computer also calculates how much exercise the shopper will have to do to burn off the calories he or she is about to buy, based on height, weight, age, and other factors. Researchers at the Technical Research Centre of Finland, the

continued on p. 25

VENTURE CAPITAL

RSS Inc.

Once a nerd preserve, the Internet communication format known as Really Simple Syndication has acquired a key tech-buzz validation: a dedicated venture capital fund, RSS Investors. John Palfrey, executive director of Harvard University's Berkman Center for Internet and Society, is one of the company's principals.

Blogs and news sites are where most Web users may have noticed those little RSS tags. Is that enough to start building businesses on?
Blogs and news feeds vaulted RSS into the limelight, but they won't be what sustains it. We're already seeing a second generation of applications—Web services like del.icio.us, which shares bookmarks, and Flickr, the photo-posting site.

Will there be more mainstream applications?
People can already use RSS to track packages with UPS or follow eBay auctions. More generally, RSS is ideal for managing any kind of info that needs to be rapidly updated. Medical records are an obvious application, and corporate communications.

The rap on technologies like RSS is that we'll end up with tunnel vision: personalization will let everyone tune out things they don't want to see or hear.
My "home page"—though that probably won't be the right metaphor—won't necessarily exclude anything. What it will do is aggregate—say, a recommendations engine based on what my friends are reading or listening to. Merge RSS with social software and you start to have something very powerful.

Spencer Reiss

ASIA KEPKA

TRANSPORTATION

Solar Flier

Its aim: around the world on zero gallons

RESEARCHERS AT Solar Impulse in Lausanne, Switzerland, are designing a solar-powered, single-pilot aircraft they hope will circumnavigate the globe in 2010.

In order to generate enough electricity from photovoltaic panels on the tops of its wings, the craft will need a wingspan of 80 meters—about that of the new superjumbo Airbus A380 jet; at the same time, however, its weight can't exceed 2,000 kilograms. Meeting these constraints requires pushing the limits of materials and design and superoptimizing electrical components, batteries, and power management systems. Leading the plane's development is the Swiss adventurer Bertrand Piccard; in 1999, he and a partner became the first people to fly nonstop around the world in a balloon.

The new craft's basic design emerged from computer models built with help from the European Space Agency and the Swiss Federal Institute of Technology in Lausanne. The propulsion system alone required the modeling of some 100 parameters ranging from the pitch of the propellers to the diameter of the motors, says Yves Perriard, an electrical engineer at the Lausanne institute. The plane will use composite structural parts and photovoltaics protected by a special polymer that allows them to function in temperatures as low as -60 °C and as high as 80 °C. Component prototyping is slated for next year, followed by manufacture in 2007 and the first test flight in 2008. Piccard's company has raised about one-third of the estimated $50 million cost of building the plane.

David Talbot

COURTESY OF BRUCE SHIELDS (EYE DRAIN); CLAUDIO LEONARDI/SOLAR IMPULSE/EPFL (SOLAR FLIER)

Prototype continued from p. 23

University of Kuopio, and the Helsinki School of Economics collaborated to develop the technology and recently completed field testing. The system, which could be deployed in Finland in two years, also allows users to access logs that list their food purchases at any time via the Internet.

Eye drain

A new implant could relieve the high eye pressure of glaucoma, which damages the optic nerve and is the second leading cause of blindness. Bruce Shields, a glaucoma expert at the Yale University School of Medicine, working with bioengineers at GMP in Fort Lauderdale, FL, has created a drain that can be slipped into the white of the eye (the sclera), near the cornea, in five to ten minutes without expensive equipment. Tissue seals around the implant, preventing excess leakage, while an interior channel precisely controls fluid flow from the front of the eye to openings in the back, regulating eye pressure. Shields has tested the device in live pigs to check that it fits and that it is biocompatible, and he is now pursuing funding for further animal and human trials. If the technology proves itself in these studies, it could represent an advance over existing surgical corrections for glaucoma. Such corrections often stop working over time, or work too well and allow too much fluid to escape the eye—which can also impair vision. What's more, these expensive, complicated, and lengthy procedures are ill suited to glaucoma patients who need treatment in poor countries.

SOFTWARE

Translation by Numbers

Language Weaver's machine-translation software aids homeland security


New software could help monitor foreign-language broadcasts.

BRYCE BENJAMIN KNEW a winner when he saw one. It was December 2001, and the infotech entrepreneur was meeting with two professors who were starting a company to commercialize "statistical machine translation." Their breakthrough: software that could learn automatically to translate text from one language into another. Benjamin believed the technology was desperately needed for purposes of both homeland security and business communication. The company's location—on the water in sunny Marina del Rey, CA—didn't hurt either. "I looked out at the view," he says, "and I thought, 'This deal has a lot of promise.'"

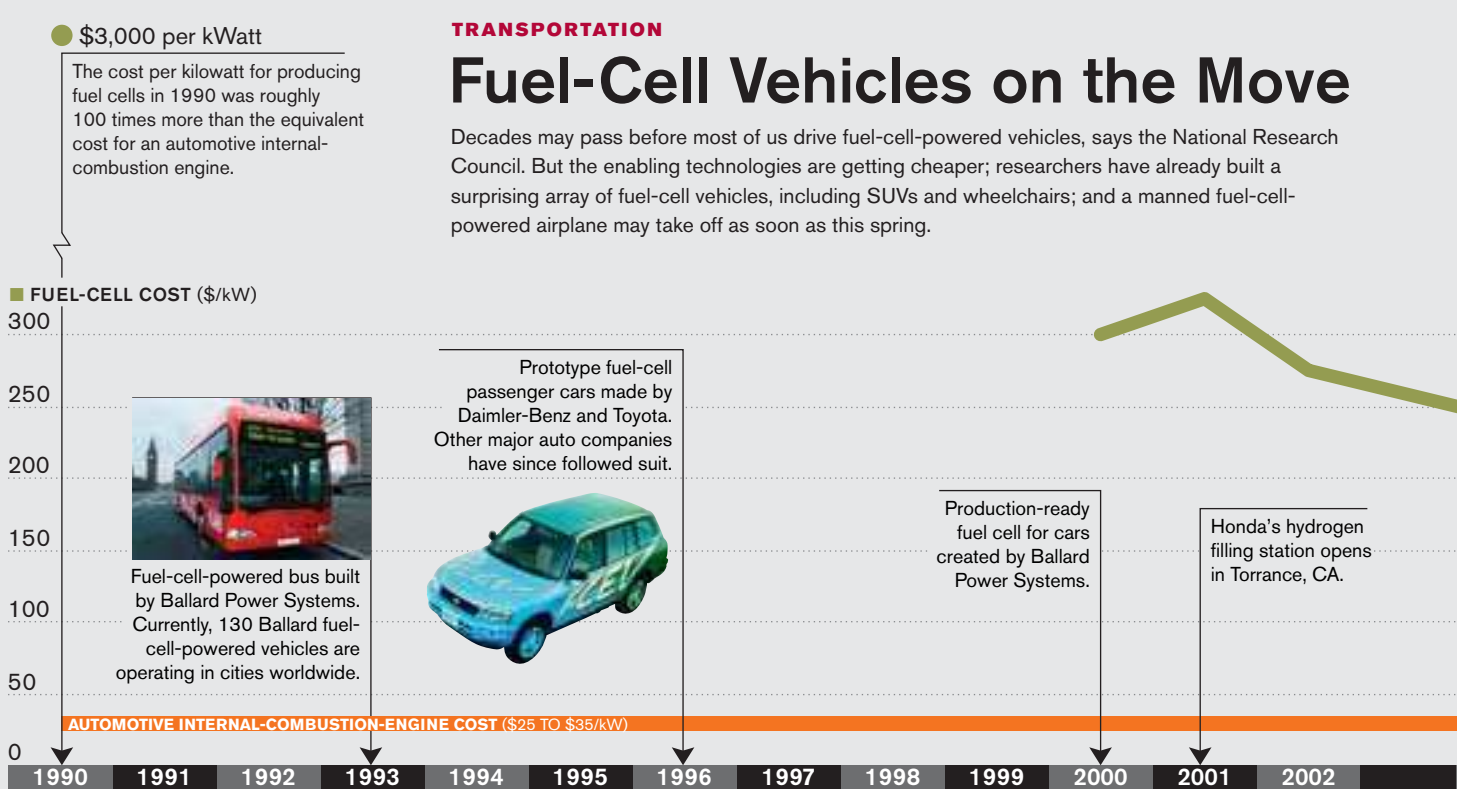
Today the trio's 35-person startup, Language Weaver, is one of the leading companies in the burgeoning field of machine translation. For U.S. counterterror translators facing a growing backlog of untranslated audiotapes and communiqués, software is increasingly the weapon of choice. Multinational corporations like Google, Yahoo, and Microsoft—not to mention smaller companies with global staff—are also driving the demand for machine translation of technical documents and Web pages. Language Weaver's software translates text between English and half a dozen other languages, including Arabic, Chinese, and Spanish. So far, the technology is most useful as a screening tool that monitors reams of foreign-language news broadcasts, chat rooms, and websites. "People use our translation software to determine the relevance of information, as a triage function," says Benjamin, the company's CEO. "It's very good at telling what a certain passage is about."

Most machine-translation systems work on individual words or use complicated sets of translation guidelines, which must be devised by linguists and coded by hand. Language Weaver's technology, which company cofounders Kevin Knight and Daniel Marcu developed at the University of Southern California's Information Sciences Institute (ISI), takes a different tack. It uses human translation data, such as United Nations transcripts, to set up "parallel corpora" of text passages in two languages, aligned sentence

TRANSPORTATION

Fuel-Cell Vehicles on the Move

Decades may pass before most of us drive fuel-cell-powered vehicles, says the National Research Council. But the enabling technologies are getting cheaper; researchers have already built a surprising array of fuel-cell vehicles, including SUVs and wheelchairs; and a manned fuel-cell-powered airplane may take off as soon as this spring.



SOURCES: U.S. DEPARTMENT OF ENERGY, FUEL CELL 2000, BALLARD POWER SYSTEMS, TOYOTA, DUFFY ELECTRIC BOAT, THYSSENKRUPP MARINE SYSTEMS, INTELLIGENT ENERGY

AP PHOTO

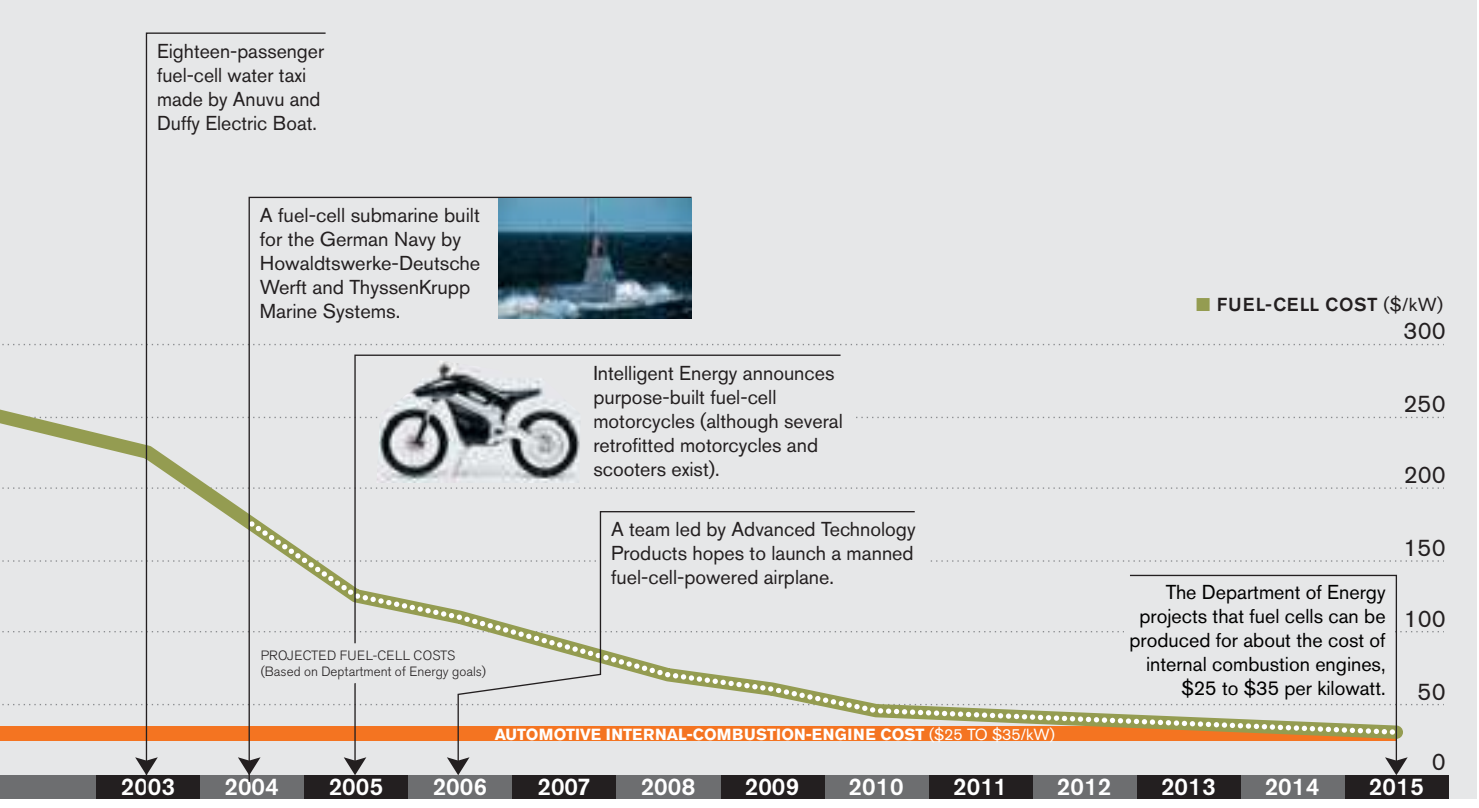
by sentence. From these side-by-side comparisons, the software learns to translate between the languages—extracting statistical patterns that indicate that a particular grouping of words in Arabic, say, tends to correspond to certain words in English. The system translates phrase by phrase, so if it encounters the words "interest rate," it will associate them with banks and finance, not curiosity and speed. And the machine-learning approach means the translations should improve with time. "The more data you add, the better the performance will be," says Knight.

Until recently, this statistical approach, which has roots in 1940s wartime cryptography, was too slow to be useful. But on a modern PC, Language Weaver's software can translate 5,000 words a minute at state-of-the-art accuracy levels; on a network of servers, it can handle up to 500,000 words a minute. The names of the company's U.S. government customers are tightly under wraps, but Benjamin says feedback from the intelligence community has been overwhelmingly enthusiastic and that the technology "played an important role in a mission that saved lives."

COMPANY: Language Weaver
HEADQUARTERS: Marina del Rey, CA
AMOUNT INVESTED: Over $4 million
LEAD INVESTORS: Palisades Ventures, In-Q-Tel
KEY FOUNDERS: Kevin Knight, Daniel Marcu
TECHNOLOGY: Statistical machine translation

But human translators won't lose their jobs anytime soon. To accurately do some translations—of, say, technical material—Language Weaver's system must be trained on similar texts translated by hand. And some experts are skeptical, since the statistical approach hasn't solved the deeper problem of getting computers to understand natural language. "It is good for the field that companies like Kevin's succeed," says Sergei Nirenburg, a machine translation expert at the University of Maryland, Baltimore County. But, he adds, "you will still have to file the product under 'Good Uses for Crummy Machine Translation.'"

Nevertheless, Language Weaver has been profitable since late 2003 and is now investigating business applications. At ISI, Knight and Marcu are testing software for a handheld translator that can handle questions and answers between doctors and patients. An outside company is also developing a real-time Arabic-English translator for instant messaging built around the Language Weaver software. But the biggest market may be multilingual search: typing a query in English could bring up scores of previously invisible foreign websites that could be translated into English. In five years, says Knight, expect to be able to read any Web page in practically any language. "You'll wonder how you ever did without it," he says. "But you'll still laugh at the translation mistakes." **Gregory T. Huang**



INTERNET

Virus Hunter

Mikko Hyppönen defends the Web against mischief

WHO WOULD HAVE thought a youth misspent playing Space Invaders and Donkey Kong could prepare you for the real world? Certainly not Mikko Hyppönen's father, who, seeing no future in computers and frustrated by his son's obsession with them, sometimes resorted to desperate measures. "He removed the fuse in my bedroom to turn the electricity off, just to get me to come to the dinner table," says Hyppönen.

But as it turned out, the hours spent taking on alien invaders served as training for battling an altogether different kind of assailant: computer viruses. Hyppönen, now the chief research officer of the Finnish computer security firm F-Secure, has become one of the most respected virus hunters in the business.

He and his team were on the front line during outbreaks of Slapper—a worm that affected tens of thousands of computers in 2002 by exploiting a vulnerability in Linux Web server software—and Sobig.F, a worm that at its peak in 2003 was lurking in one of every 17 e-mails. He is also credited with being the first to warn about the May 2004 outbreak of the Sasser worm, which infected hundreds of thousands of computers across the globe—stopping train traffic in Australia, delaying Delta flights in the United States, and paralyzing Taiwan's national post office. But where Hyppönen really shines is in predicting new threats long before they occur. He warned of the possibility of document-infecting macroviruses, such as the infa-

Virus writers are no longer interested in notoriety, according to Hyppönen. Today they're after money.

mous Melissa virus, in the early 1990s, two years before they started to appear, and he predicted mobile-phone viruses several years before the first one struck.

Hyppönen doesn't attribute his skill at tackling malware to video game–honed strategies per se, but rather to the fundamental knowledge of computers that he developed in his teenage gaming years. Frustrated by how long games took to load on his Commodore 64, he taught himself assembly language so he could write code that would speed up the process. By 14 he was already making money from his programs. "I was selling them to floppy magazines, magazines published on floppy disks," he says.

The skills he picked up during this period would serve him well. He joined F-Secure (which at the time was called Data Fellows) in 1991, and a year later, he got his first taste of decoding a virus. Back then, viruses were a relatively new phenomenon, and resources for dealing with them were sparse. "I couldn't run the virus on a machine to see what it did because we couldn't spare one. They were too expensive." Instead, he had to print out nearly 40 pages of code and meticulously go through it line by line, trying to figure out what the program did. The process took about three days—long enough to get him hooked.

Today, of course, computers are cheap, so running viruses isn't a problem. But Hyppönen still uses his reverse-engineering skill in trying to predict new threats. Virus writers are no longer interested in notoriety, he says; these days they are after money. He believes virus writers are now teaming up with spammers and designing viruses that try to evade detection.

So after mobile phones, what could possibly be the next target? Skype, according to Hyppönen. The peer-to-peer Internet phone service is an ideal mark for malware writers because it is designed to bypass firewalls.

While he waits to begin his next battle with virus writers, Hyppönen directs his passion for reverse engineering toward rebuilding and restoring old pinball machines and arcade games. It is not just about reclaiming part of his youth, he says. It is also about preserving a golden era in computer history. "If no one else saves them, they will disappear."

Duncan Graham-Rowe

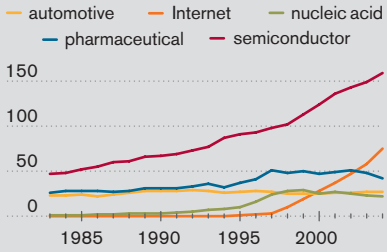
SEAN MCCABE

INTELLECTUAL PROPERTY

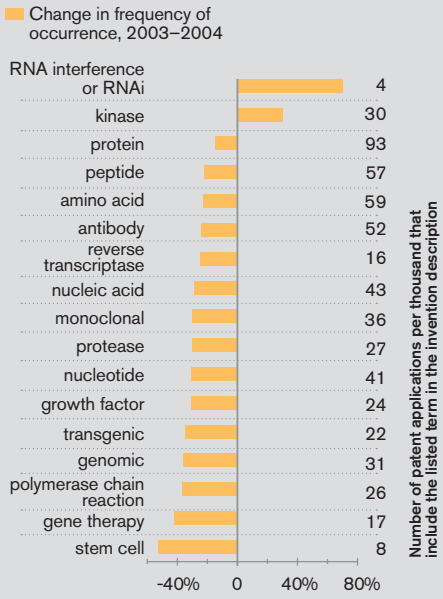
Biotech Patenting

Biotech patenting appears to be on the decline. In 2004, the U.S. Patent and Trademark Office issued only 3,998 patents that contained the phrase "nucleic acid" in their invention-description sections—or just 22 per 1,000 patents—down from a high of 4,990 in 1999. The number of patents containing the word "pharmaceutical" also fell during this period.

Number of patents containing each keyword per 1,000 patents issued



Biotechnology terms appearing in patent applications



SOURCE: FINNEGAN, HENDERSON, FARABOW, GARRETT, AND DUNNER

75 years ago in *Technology Review*

The Plastic Age

(October 1930, p. 25)

Above the economic horizon a new industry, the manufacture of plastics, is climbing into prominence. Dr. Wilson Compton, Executive Secretary of the National Lumber Manufacturers Association, declares that the aggregate value of plastic products in the United States is already equivalent to one-tenth that of the products of the lumber and wood-working industries combined, and the editors of *Plastics* assert that the volume of the plastics business has practically doubled every year, bringing its total this year up to one-quarter of a billion dollars.

What are plastics and how are they used? The material of which phonograph records are made is a commonly known product that falls into the plastic classification and, of course, there is celluloid. The first is known chemically as a shellac base plastic and the second as a cellulose nitrate plastic, but both of these are old stories. It is the discovery and spectacular development of the phenol formaldehyde resins such as Bakelite that has created an industry that approaches the magnitude of the lumber business and bids fair to challenge the supremacy of many others.

One large firm, for example, is offering for the first time "Beetle" ware, a type of tableware that is thin, light, and colorful, that will not scratch or chip or break under ordinary usage. Surely a boon to hotels and housewives!

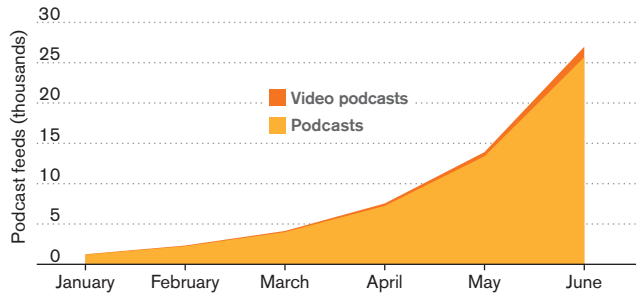
Data Mine

Podcasting Takes Off

Podcasts—those amateur or professional audio or video programs delivered automatically to a subscriber's computer or MP3 player—let consumers listen to their favorite shows whenever and wherever they want. But though the technology for podcast subscriptions has been around for several years, the mainstream has only recently caught on. An explosion in podcasts' popularity in the first half of this year, culminating in the launch of a podcast directory at Apple's iTunes online music service, has providers scrambling to keep up with server demands and businesses looking for ways to turn a profit. Several factors may have sparked podcasting's new popularity: Broadband access and new applications and directories make acquiring podcasts painless, for example, and other programs make creating them a snap. Phenomenal sales of iPods and other portable digital music players, which let people take the show on the road, also likely have helped. **Kevin Bullis**

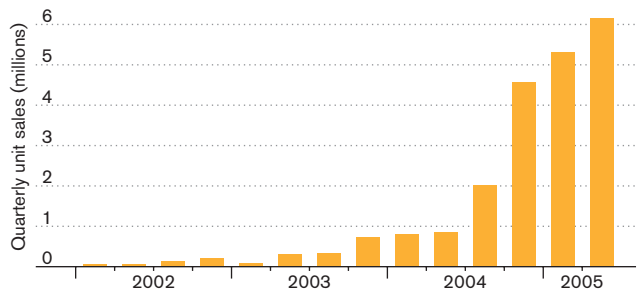
Feeds multiplied in the first half of 2005

Blinkx.tv, a search service and directory, has scoured the Web for podcasts. It found dramatic growth.



Jump in iPod sales preceded podcast boom

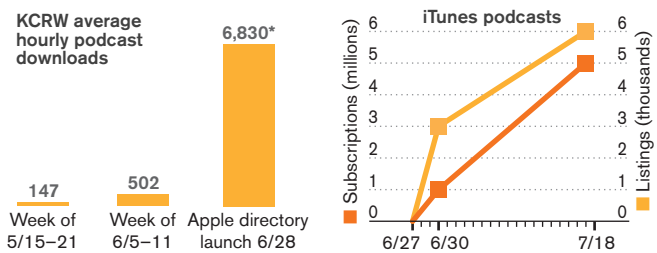
The iPod is by no means the only device that can play back podcasts; but the increase in podcasts followed a surge in iPod sales.



SOURCE: APPLE COMPUTER

Podcasts at iTunes turn up the heat

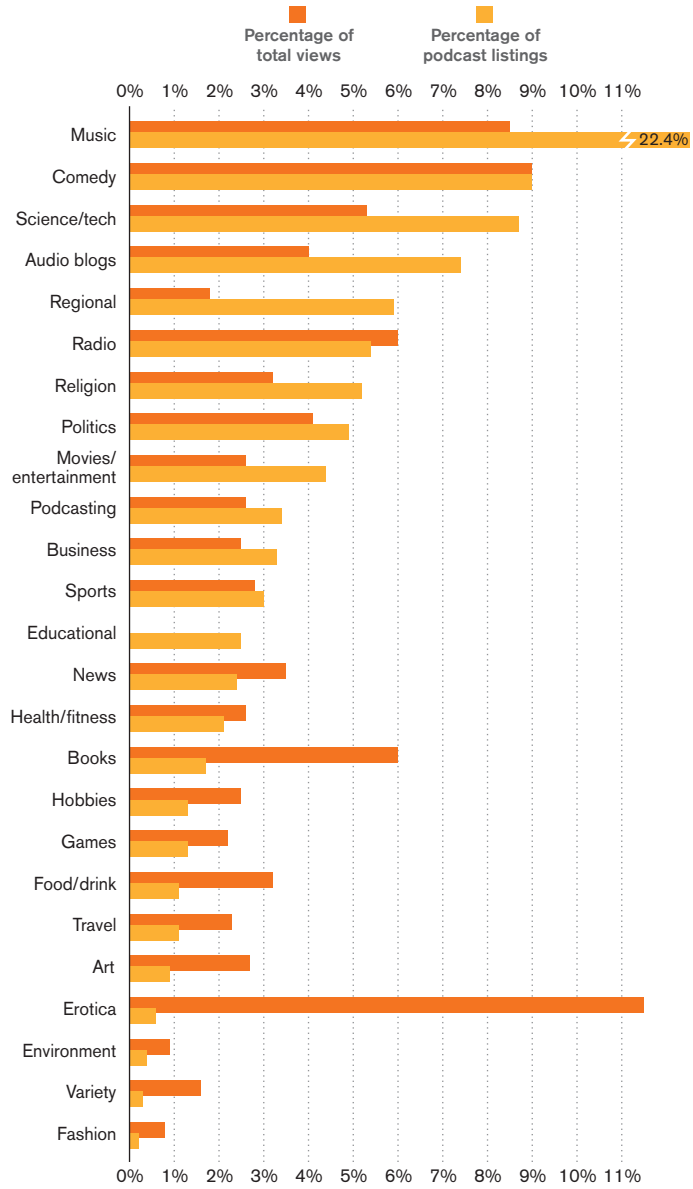
Apple iTunes' podcasting directory grew quickly, putting high demand on providers' servers. Public radio station KCRW's servers could not handle the load, so Apple's servers took over the hosting of its podcasts.



*DATA IS BASED ON DOWNLOADS FROM KCRW SERVERS UNTIL 7:00 P.M., WHEN APPLE SERVERS TOOK OVER TO COVER DEMAND

Podcasts come in a variety of flavors

Figures from Alex Nesbitt, founder of the Digital Podcast directory, show a gap between the kinds of podcasts available and the kinds that people actually downloaded this past July. He sees opportunities for podcasters and advertisers in categories that have high demand but relatively few podcasts, such as erotica.



Funding of Innovative Startups

Company	Founded	CEO	Recent funding	Key investors	Technology	Prospects
FiberTower	2001 San Francisco, CA	Scott Brady	$150 million	Crown Castle International, Oak Investment Partners, Goldman Sachs, Tudor Investment, and Meritech Capital Partners	Wireless networking systems that connect cell towers to communications backbones	**Already has several of the largest U.S. wireless carriers among its customers.**
Affymax	2001 Palo Alto, CA	Arlene M. Morris	$60 million	JAFCO, Bear Stearns Health Innoventures, Bessemer Venture Partners, Merlin BioMed Group, Diamond Capital Company, Apax Partners, MPM Capital, and Sprout Group	Peptide-based therapeutics for kidney disease and cancer	**Its lead product, Hematide, began phase II clinical trials in July.**
Altea Therapeutics	1998 Tucker, GA	Eric Tomlinson	$30 million	Aperture Venture Partners, Domain Associates, Venrock Associates, vSpring Capital, KBC, Quilvest, CX Ventures, and Rockport Ventures	New types of drug-delivery skin patches	**Several products are in clinical trials, including an insulin patch for treatment of diabetes.**
Zensys	1999 Upper Saddle River, NJ	Per Nathanaelson	$16 million	Bessemer Venture Partners, Palamon Capital Partners, and Vaekstfonden	Wireless chips that allow consumers to remotely monitor and manage home appliances and devices	**If the time is finally right for "smart homes," Zensys could have bright prospects.**
NextHop Technologies	2000 Mountain View, CA	Edward M. Cluss Jr.	$10.5 million	Labrador Ventures, New Enterprise Associates, Duchossois Technology Partners, and Parker Price Venture Capital	A series of software products for both wired and wireless networking	**Core technology is derived from National Science Foundation research; the company already sells a number of products.**
JasperSoft	2001 San Francisco, CA	Paul Doscher	$8 million	Partech International, Doll Capital, Morgenthaler, and Discovery Ventures	Open-source business intelligence software	**Company claims its product is downloaded more than 22,000 times a month and used at over 10,000 companies in 50 countries.**
Labcyte	2003 Sunnyvale, CA	Elaine J. Heron	$21 million	Cross Atlantic Partners, Hambrecht & Quist Capital Management, Bay Area Equity Fund, Abingworth Management, Delphi Ventures, Alloy Ventures, and Sprout Group	Low-volume liquid-handling equipment for labs	**Labcyte's liquid-handling system is already being sold to drug companies.**

Will take time to reach market **Strong competitive position** **High-benefit, high-risk technology**

Company Spotlight

Zensys While remote, automated control of home appliances has always been an idea whose time has not quite arrived, the newest generations of wireless mesh technologies could make this long-awaited innovation widely affordable at last. And Zensys, a New Jersey company that sells radio-based mesh networking hardware that allows devices to be controlled remotely, is betting that consumers are finally ready to pay for "smart homes."

The list of chores that can be automated is potentially limitless, and gets longer as houses get bigger and more complex. The basics are controls of lighting, security systems, watering, air-conditioning, and heating, but automation also can be extended to include pool management, child-safety controls, curtains, and appliances.

Venture capitalists have invested in several other companies in this sector recently, but Zensys could have an advantage over its competitors in that it has lined up relationships with an impressive set of home-control companies.

FiberTower Its latest round of $150 million in financing, led by existing investor Crown Castle International, brings FiberTower's total venture capital funding to an impressive $225 million.

What makes FiberTower attractive to investors is that it offers an alternative to outdated segments of existing wireless networks. FiberTower, whose products use a combination of radio and fiber-optic technologies, is targeting the infrastructure that connects cellular towers with the core communications network. These connections, known as "backhaul" facilities, are facing the growing load brought on by voice, video, and other data. Increasingly, as the demands on the existing networks have taken off, conventional backhaul facilities are a source of bottlenecks and costly outages for network operators.

FiberTower launched its backhaul facilities in 2002 and now counts four of the five largest U.S. wireless carriers among its customers. It says it will use the latest funding to further expand its services.

Andrew P. Madden

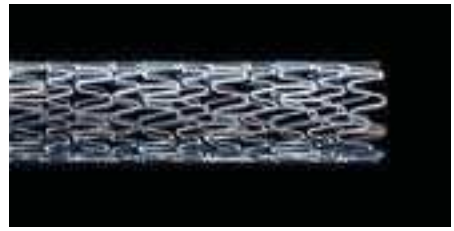
The Lucrative Elution

THE CASE: When Boston Scientific needed a way to prevent scar tissue from covering up its coronary stents, it turned to a little-known company called Angiotech Pharmaceuticals. The odd partnership yielded one of the most financially successful medical devices in history—and signaled a new way for medical-device companies to improve their wares.

In 1996, Johnson & Johnson was the undisputed king of bare-metal stents. Stents are the mesh tubes that prevent arterial collapse after balloon angioplasty, the principal treatment for atherosclerosis: A balloon is inserted into an artery to clear away plaque and is removed. Then a stent containing another balloon is inserted into the artery. The balloon is inflated to open the blocked artery and push the stent against the arterial walls; this balloon is then deflated and removed. J&J held a strong patent portfolio that gave it dominance in the U.S. stent market. It also led in Europe, where it faced stiffer competition.

Stents revolutionized the treatment of atherosclerosis in coronary and peripheral arteries, but they did little to address one of the chief problems with balloon angioplasty. In about 30 percent of cases, scar tissue formed around the site of the injury, causing the artery to close again, a setback called restenosis. Stents reduced the restenosis rate slightly, but it was still high. Today, restenosis in coronary arteries afflicts less than 10 percent of patients thanks to the development of the drug-eluting stent (DES), which slowly releases a drug that inhibits the growth of scar tissue. Drug-eluting stents now command more than 90 percent of the $3 billion U.S. coronary-stent market, according to the Millennium Research Group. DESs have not been approved for peripheral arteries.

Johnson & Johnson pioneered the new generation of stents, but the $50 billion company lost its dominant market position to a partnership between medical-device company Boston Scientific of Natick, MA, and Angiotech Pharmaceuticals of Vancouver, BC. The two companies signed a pact in 1997 that led to the development of Boston Scientific's Taxus stent, which was introduced in the U.S. in March 2004.



Boston Scientific

FY 2004 revenues: $5.6 billion
Employees: 17,500
Taxus's share of 2004 revenues: 38%

Taxus was arguably the most successful new medical product in history, netting more than $1.4 billion in sales in its first nine months in the U.S. alone. And that's despite the divergent business models of the companies that created it.

The project dates to 1996, when Bill Hunter, cofounder and chief scientific officer of Angiotech Pharmaceuticals, approached J&J and other stent makers with his own solution to the restenosis problem. His company had obtained a license to produce paclitaxel—better known by its brand name, Taxol—an anticancer drug derived from the Pacific yew tree. Approved as an anticancer agent in 1992, it is marketed by Bristol-Myers Squibb. Stents coated with the drug worked remarkably well in animals, keeping rat arteries clearer than uncoated control stents did. Hunter made the rounds of the stent manufacturers, including J&J, Medtronic, Guidant, Boston Scientific, and Cook.

Angiotech and J&J engaged in discussions, though J&J was already working on a DES that would utilize sirolimus, an immunosuppressant marketed by Wyeth. Hunter talked with the other companies while keeping an eye on Europe, where J&J was also a market leader, but nothing was settled. New stents entered the market often, and "other companies were taking market share from J&J," says Hunter.

As he pondered his options, Hunter received an unusual offer. Cook and Boston Scientific were longtime competitors, but in order to make a more attractive offer to Angiotech, they had decided to band together, proposing a joint agreement that would allow both to develop paclitaxel-coated stents. The financial terms for both companies would be identical.

"They said, 'We understand that if you want to deal with one company, it would be the market leader [J&J], but would you be more interested in dealing with the number two and number three companies?' We thought it would be a phenomenally good idea," says Hunter, especially in light of the situation in Europe, where, he says, "cardiologists were switching brands almost monthly. It became very difficult to predict who would have the best stent." And no matter how good the drug, if it were matched with a lousy stent, it wouldn't have a chance. "We felt with two horses, we doubled our chances that we would be competitive." In the summer of 1997, the three companies signed a pact.

Boston Scientific's Forward Thinker

Using a drug was a novel approach to the problem of restenosis. Stents work on a simple principle: a balloon expands the stent to support the arterial wall and is then deflated and removed. Companies had tinkered with stent designs, trying to prevent restenosis, but with little success. "It was surprising that [only] a few companies were forward-thinking enough to look at biological approaches," Hunter says.

Most of Boston Scientific's products were typical low-risk medical devices, but

COURTESY OF ANGIOTECH PHARMACEUTICALS

it was open to unusual approaches. After a stint in Pfizer's orthopedics division, Jim Barry joined Boston Scientific in 1992 to work on using angioplasty balloons to deliver drugs or even to assist in gene therapy. But progress was slow.

Barry found out about paclitaxel when he met Angiotech cofounder and consultant Lindsay Machan at a 1996 radiology meeting in Vancouver. Because restenosis is a problem with a number of implanted medical devices, and Boston Scientific manufactures devices for gastrointestinal, urological, and other uses, Barry realized that paclitaxel was "something we could leverage across all our divisions," he says. He also liked that the drug was well known and had an extensive clinical history as a cancer treatment. "I thought it might reduce the regulatory burden," says Barry, who is now Boston Scientific's vice president of corporate research and advanced technology development.

Soon after he returned from Vancouver, Barry began to campaign for an agreement with Angiotech. Company managers were receptive, he recalls, but leery of the drug-eluting stent's potentially long development time: they knew they were looking at much more than the 12 to 18 months it usually takes to bring a new medical device to market. Boston Scientific also had little in-house expertise in the clinical-trial and regulatory-approval process for drugs, which is different from—and often more stringent than—that for medical devices. At the same time, it knew it might have a blockbuster on its hands.

And Angiotech was an attractive partner. Earlier in 1996, its paclitaxel-coated stents had been tested for the treatment of patients with cancer of the esophagus. As Angiotech had hoped, the drug prevented new tissue from growing over the top of the stents. Subsequent studies have since shown that paclitaxel works by inhibiting cell migration, markedly slowing the accumulation of scar tissue.

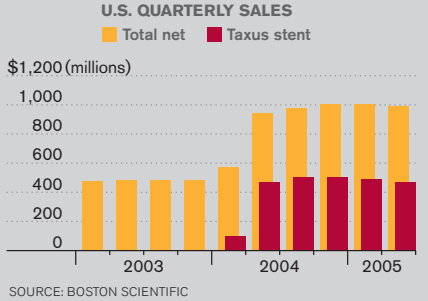
Ultimately, Boston Scientific decided in favor of partnering with Angiotech and entered into its novel alliance with Cook. For his part, Angiotech's Hunter believes that Boston Scientific and Cook were ideal partners. Companies that trail the market leaders are typically more amenable to taking risks on new technologies. "When you go to a market leader with a disruptive technology, most of the time they aren't interested," says Hunter. "If they already have a dominant position in a lucrative business, taking a risk on something that will cannibalize their own product is not something they're likely to do. We talked to [the companies that trailed in market share], and those are the kinds of companies that will look up and say, 'How can I get a piece of that pie?'"

Hunter notes that J&J was unusual in that it led the bare-metal-stent field and yet had a DES program. "They deserve a lot of credit for that," he says. Angiotech has since signed deals with Broncus Technologies for the use of paclitaxel in an implanted device for emphysema patients and with CABG Medical for coronary artery grafts for use in bypass surgery. Companies interested in Angiotech's expertise are "the ones trying to claw their way up. It's not because we don't want to work with the market leader," says Hunter with a laugh. "It's not like we have a predilection for the underdog."

With their deal signed, Boston Scientific and Cook set to work on DESs. Cook made it to the market first, introducing the paclitaxel-coated V-Flex Plus PTX coronary stent in Europe in September 2002. However, after some disappointing clinical trial results and a failed merger with Guidant, the company withdrew from that market in 2004 to focus instead on making DESs for the femoral artery. "They were the first to launch a paclitaxel-coated coronary stent, and that was a big high...but ultimately they didn't have the impact on cardiology that we had hoped," says Hunter.

Taxus Stent Makes Boston Scientific Sales Soar

After years of flat sales, 2004 net sales increased 82 percent over 2003, largely due to $1.57 billion from the Taxus stent.



SOURCE: BOSTON SCIENTIFIC

"It Felt Like a Vise"

It would be Boston Scientific, instead, that would have that impact. But creating the Taxus stent was not easy. A critical technical hurdle was the development of a coating for the stent that would release the paclitaxel slowly for about six months after surgery, after which the scarring response dampens. Angiotech had already tackled the problem, but Boston Scientific preferred to develop its own technology.

That left Angiotech on the sidelines as Boston Scientific methodically designed and developed its new stent. The biggest questions were about drug dosage and rate of release. Barry started with a large dose just to show that the drug-coated stent would indeed work in pig arteries. Satisfied that it had the desired effect, he performed a series of follow-up studies, each time halving the drug dose until he found a minimum effective dose.

The next step was to tinker with the polymer to find the optimum rate of release. Restenosis is essentially a case of the healing process getting carried away, with smooth-muscle cells migrating to the site of the injury with such exuberance that the artery is once again blocked. Paclitaxel inhibits that process, but Barry didn't want to shut it down completely. He used trial and error to find a polymer with a drug release rate that would allow just enough cell migration to promote healing yet prevent it from going overboard.

Each study took three to six months to complete. Some of them could be done concurrently, but other studies had to be done consecutively, and the development dragged out. Hunter became anxious. He watched as J&J took over the lead in DES development. "At some point, I think we were even or a little ahead of J&J in terms of discovery," Hunter recalls. But with every experiment Barry's team performed, its chances of being first to market dwindled. J&J's Cypher stent was approved in April 2003, and in October of that year, J&J published a study that reported impressive research results: Cypher had a restenosis rate of 5.9 percent, compared with 42.3 percent for bare-metal stents.

As it became clear that J&J would beat them to market, Boston Scientific and Angiotech grew worried. "If you go back to the financial-analyst reports at the time, they thought that J&J having a one-

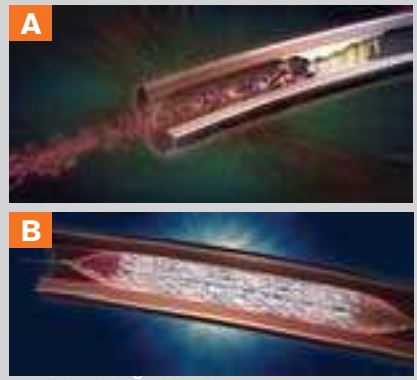
year lead would be hard for Boston Scientific to overcome. [They felt that] doctors would become very comfortable with J&J's stent," Hunter recalls. Barry's methodical approach drew criticism from market analysts, and even from Hunter. "I remember telling [Boston Scientific CEO] Jim Tobin, 'We've got the polymer, we know the drug release [characteristics], we should go forward....As a scientist, as soon as you have positive animal data, you can't understand why you're not treating a patient the next day. But Boston Scientific had to work to get the polymer formulated just right. They had to get uniform drug delivery. There are so many of those steps. Things you think should be solvable in a week end up taking a year."

Hunter was not alone in his discomfort. Barry felt pressure from both Hunter and Tobin. "I would be sitting in this big conference room, alone with [Tobin]. One day he looked at me and said, 'Jim, we're fifth in a three-horse race.' I had Bill on one side of me and Jim Tobin on the other side. It [felt] like a vise," Barry says.

In the end, though, both Tobin and Hunter deferred to Barry's drive to get the release kinetics just right, and in retrospect, it seems it was a wise decision. J&J did indeed ultimately beat Boston Scientific to market, but it had supply problems. This resulted in a shortfall that angered patients and cardiologists.

How the Drug-Eluting Stent Works

Patients with atherosclerosis suffer from plaques that can reduce blood flow or rupture and lead to blood clots (A). Stents are wire mesh cylinders used to reopen clogged arteries. Surgeons insert the stents in a collapsed position, then open them by inflating a balloon. The balloon is then deflated and removed (B). A drug-eluting stent's polymer coating gradually releases a drug to prevent restenosis, a condition in which inflammation and the formation of a layer of cells over the stent can close off the artery. The drug counters inflammation and interferes with the ability of the cell layer to form, and so prevents the reclosing of the artery.



SOURCES: ANGIOTECH PHARMACEUTICALS, BOSTON SCIENTIFIC

Moment of Truth

The Taxus stents passed through the early clinical trials, performing well. In 2003, Taxus was launched in Europe, but a final trial dubbed Taxus 4 remained before the FDA would approve the stent for the U.S. market. To much press coverage and fanfare, it was announced that the results of the pivotal Taxus 4 trial would be presented at the Transcatheter Cardiovascular Therapeutics meeting in September 2003. The night before, Hunter, Tobin, and others from the two companies gathered together. Hunter recalls his trepidation. "I hadn't seen the data, Boston management hadn't seen it, and there were lots of rumors of failure. I remember Tobin: he'd look at a slide and laugh and hand it to me, and then he'd look at the next slide and laugh again." The trial had been a big success, with results on a par with J&J's. Restenosis occurred in 7.9 percent of patients receiving the Taxus stent, compared with 26.6 percent of patients receiving bare-metal stents.

Hunter now believes that his angst was unnecessary. "Boston decided this could be a blockbuster, and they wanted to make sure it was bulletproof before they went forward. In the end, you could see the benefit. When the product launched, and there was all this demand, they were able to meet it right away," Hunter explains. The Taxus stents did suffer some difficulties. Boston Scientific recalled about 85,000 stents from the market in July 2004 because of malfunctions in the catheter system that delivers the stent, but those problems were solved without incurring a significant loss of market share.

Taxus overtook J&J's Cypher stent quickly. Boston Scientific sold about $42 million worth of Taxus stents in the first 10 selling days alone. A little more than a month after launch, the company estimated the Taxus accounted for 70 percent of DES sales. Today, Taxus sales constitute 30 percent of Boston Scientific's income. So why did the Taxus so rapidly displace the Cypher? After all, the stents' clinical trials were approximately equivalent, says Rui Avelar, senior vice president of medical affairs and communications at Angiotech. "Despite the fact that we beat them, I think they're both very good, comparable stents. You'd be hard pressed to say there's a medical difference."

In fact, Boston Scientific may have its competition to thank for the Taxus's ascendance. J&J made an operational mistake when it introduced the Cypher. It aggressively distributed the results of its trial, generating a great deal of press coverage and buzz among cardiologists. As launch day approached, J&J had to deal with a setback: the FDA told J&J that it couldn't use stents more than six months old. This forced J&J to discard thousands of stents just a few weeks before the launch. According to *Fortune* magazine, when the Cypher hit the market, 100,000 patients were waiting for stents, and J&J had 40,000. That made the Cypher vulnerable when Boston Scientific introduced the Taxus.

The Future

Partnerships with pharmaceutical companies are now the most common form of collaboration in the medical-device industry, and cross-fertilization between industries is likely to continue. It's a natural trend, says Hunter. Most medical devices were initially developed decades ago, and years of improvements and fine-tuning have narrowed the gap between competing devices, leaving companies casting about for new ways to distinguish their products from competitors'. "Companies are looking to biology to provide product differentiation," says Hunter.

That's something that Angiotech is counting on. After its success with the Taxus stents, the company entered into similar agreements with Broncus, CABG Medical, and other companies. Cook also continues to work with paclitaxel-eluting stents; its new Zilver system is intended for use in the leg. Angiotech sees the possibility of building more business on the kind of arrangement it made with Boston Scientific. Its goal is to become "effectively the pharmaceutical arm of the medtech industry," says Avelar. Angiotech, and the trend its partnerships represent, are both worth watching.

Jim Kling

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The Customer Is Sometimes Wrong

THE CASE: In 1999, when former Oracle executive Marc Benioff founded Salesforce.com, companies bought software and ran it on their own computers. The idea of renting access to business software running on another company's servers sounded insane. But today, "software as a service" is a viable business led by Salesforce, whose best early decision went against the advice of potential investors and customers.

YOU MAY HAVE noticed lately that you're spending less time using the software you purchased for your PC and more time using websites that offer the functionality of traditional software. For instance, if you manage your e-mail using Gmail, or you've used Google Maps *(see "Killer Maps," p. 54)*, then you are part of a trend shaking up the software industry: "software as a service."

Software-as-a-service can be a boon for consumers: it usually costs less than store-bought software and requires users to install and boot up nothing more complicated than a browser. Corporations see the same benefit, but multiplied across dozens of business units and hundreds or thousands of employees. Many of those corporations have suffered through years of dependence on complex, expensive, and temperamental "enterprise" software, which manages everything from sales and customer support to inventory, shipping, payroll, and planning. Software-as-a-service, then, can represent a welcome alternative to purchasing software packages from traditional vendors like IBM, Oracle, and Siebel Systems.

One company that was recently looking around for alternatives is ClearCube, an Austin, TX–based maker of specialized hardware and software for the government, health-care, and financial sectors. ClearCube had long been using customer relationship management (CRM) software from Siebel. CRM software helps organizations keep track of current and prospective customers. It tracks customer contacts, logs sales visits, generates forecasts, and generally helps to convert sales leads into deals. But at ClearCube, only 35 percent of the sales staff was willing to use the software, says Dean Dresser, the company's controller. "It was a very painful, broken system," he says. "It was difficult and unwieldy to manage. Every time we went through an upgrade, all the customization we had done on the previous version would disappear." And because people didn't use it consistently, Dresser adds, the software couldn't produce consolidated forecasts. "People would send me their weekly reports in Word or Outlook or Excel or on the back of a pizza box. As a result, we had no way of knowing the probability of closing deals."

Salesforce.com CEO Marc Benioff

COURTESY SALESFORCE.COM

Salesforce.com

FY 2005 revenues: $176 million
Employees: About 1,000
Capital raised in June 2004 IPO: $110 million

In 2003, Dresser's boss gave him permission to do something about it. After looking at various makers of CRM systems, Dresser settled on up-and-comer Salesforce.com. Beginning in April 2004, ClearCube gradually moved from the Siebel system over to Salesforce's Web-based system. As we'll see later, the decision to switch paid off for ClearCube. But to push it through, Dresser had to overcome a lot of resistance within his own company, especially from its IT department, which complained about losing control over the company's data.

As Dresser learned, that was a concern executives at Salesforce had encountered many times before—indeed, since the founding of the company. And it was one they had decided to ignore.

Drawing a Line

Marc Benioff left Oracle in 1999 to start a company that would sell CRM services over the Web. Why CRM? "It's one of the best beachheads for on-demand software because it's especially amenable to the hosted model," says Clarence So, who joined Benioff six months after the founding of the company and is now the vice president and general manager of community, overseeing relations between Salesforce's customers and its partner software development companies. "Salespeople are all over the place," So points out, and it makes everyone's lives easier if all they need to do to report their results and get their next assignments is find an Internet connection, open a browser, and log on to Salesforce.com.

But that logic wasn't immediately apparent to prospective investors, whom it was So's first job, from 1999 to 2001, to lure. "People were saying, 'This stuff will never fly. Companies will never let anyone host their data.' The word 'control' came up a lot." According to So, the investors told Benioff to build both a self-contained CRM package and a hosted version, believing that the hosted version would serve to attract customers but that these

customers would eventually want to bring the software in-house.

The pressure to follow this advice was great. "In 2000 and 2001, every VC [venture capitalist] was going to their portfolio companies and forcing them to adopt a technology model that said, 'Give customers choice. If your customers want you to host the software, do that, but if they want to bring it in-house, let them do that,'" says Tien Tzuo, Salesforce.com's senior vice president of product management. "A lot of startup businesses built technology models to accommodate this choice."

Benioff and his small staff—working mostly out of Benioff's home—considered it a bad idea to grant their customers the in-house option. So they did the unthinkable: they walked away from the prospective investors who insisted on the "choice" model. "We've taken plenty of big bets, and the bet we took in 1999 was that we were not going to play that game," says So. "We were going to go whole hog into the hosted model. Marc felt that the control issue was just an emotional issue, not really a rational issue."

It was Benioff's long-standing belief in the rationality of the hosted-software model that made him unwilling to compromise. In 1999, before he had his first customer, he had determined that the only way to make his service more attractive than competing CRM systems was to host all of his customers' data in one place, which would reduce costs and simplify maintenance and upgrades.

"We were going to go whole hog into the hosted model. Marc [Benioff] felt that the control issue was just an emotional issue, not really a rational issue."

Salesforce's low prices, which haven't changed since 2001, may have helped some customers get past their control worries. For small businesses (having five or fewer employees), Salesforce charges $995 per year. For medium-sized businesses, it's $65 per user per month, and big corporations pay $125 per user per month. Running traditional CRM software can cost a company twice as much, once hardware, IT staffing, and other costs are factored in over the five-year lifetime of a typical software package, according to a study by the Yankee Group, a technology consultancy in Boston.

ClearCube controller Dresser eagerly testifies to the savings Salesforce's hosted service brought his company. "The total cost of ownership is much lower than the traditional CRM software," Dresser says. "Also, we're not dependent on our IT department to fix stuff anymore, we didn't have to put in a huge effort up front, and upgrades take place instantaneously without affecting our custom modules." Indeed, Dresser attributes part of his own company's international expansion, growing revenue, and increasing profit margins (its revenues in fiscal year 2004 tripled over 2003, and its profit margin more than doubled) to Salesforce. "There is no way we could have managed our growth into the four corners of the world without an integrated CRM," says Dresser.

The migration of a host of other businesses from Siebel and other CRM providers to Salesforce has given the company the lion's share of the market for Web-based CRM services. Salesforce increased its customer base by 40 percent in 2004, from 9,500 to 13,300, according to Forrester Research. Quarterly revenues almost doubled between the first quarter of 2004 and the same quarter a year later, from $35 million to $64 million, with profit margins hovering at about 5 percent. And Wall Street has rewarded the company handsomely, pushing its stock price from $11 per share at the time of its June 2004 initial public offering to about $24 per share in July 2005.

Siebel Systems still sells more CRM software overall but is struggling. Founded in 1993 by another Oracle alumnus, Tom Siebel, the company was initially dismissive of Salesforce.com's prospects. Lately, however, Siebel has been following an "if you can't beat 'em, join 'em" strategy, purchasing a hosted-CRM company called UpShot in October 2003 as well as rolling out an on-demand version of its own CRM software. But it may be too little, too late: Siebel's stock has plummeted from more than $100 per share in late 2000 to less than $10 this summer, and the company posted a $50 million loss for the second quarter of 2005.

Now that the market has validated Benioff's original bet, Salesforce has begun encouraging customers to develop their own complementary programs. It's already given them a software tool called CustomForce, which ensures that their custom modules will run on the operating system, called SForce, that underlies Salesforce.com's entire product line. It also offers something it calls MultiForce, a user-interface improvement that lets customers switch between Salesforce.com's sales and support software, their own in-house applications such as e-mail and spreadsheets, and new applications developed by Salesforce.com partners.

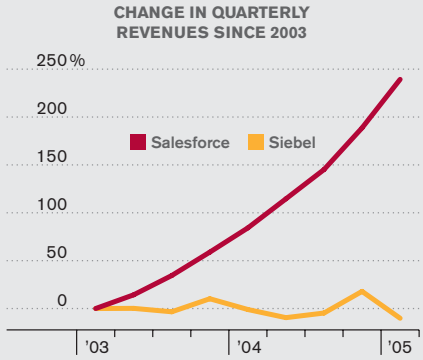
If that combination sounds familiar, it's no accident. Clarence So likens MultiForce to Microsoft Windows and CustomForce to Visual Studio (Microsoft's tool for developing Windows programs). In fact, Benioff has made no secret of his ambition to build Salesforce.com into the Microsoft of Web services. "Our big bet now is that this is really going to be as big as Microsoft was in the client-server world, and as IBM was in the mainframe world," says So.

Salesforce has attracted believers who say that as long as Benioff is in charge, the company has a shot at the big time. "Without question, his personality and his will to make this company grow and validate this space have been absolutely critical," says Nick Blozan, a senior vice president at OpSource, a Santa Clara, CA–based company that manages software delivery for software-as-a-service providers. "He's the right guy at the right time. He's pointing out that there are fundamental dissatisfactions with the old model, and I think you'll continue to see all of this accelerate."

Wade Roush

Revenues Climb for Salesforce.com

Salesforce's approach spurred growth, while competitor Siebel's revenues stayed flat.



SOURCES: SALESFORCE.COM AND SIEBEL SYSTEMS

Cleaning Up

THE DECISION: In the midst of the tech crash, Corning put big money into the development of a sleepy technology: pollution filtration for diesel engines.

CORNING HAS PIONEERED some of the sexiest technology of the past 100 years. The incandescent light bulb. The picture tube for color TVs. Windows for every NASA spacecraft. The glass screens for laptop computers and flat-panel TVs. And, yes, optical fiber. They invented it.

Then there's the tailpipe business.

In the world of glamorous technology, it never hurts to have a dependable trade in something like cleaning up the exhaust of cars, trucks, and buses. More than 30 years ago, Corning developed the honeycombed materials that have become the guts of catalytic converters, dramatically reducing pollution. "Environmental technology," as Corning calls it, has been a steady business for the company ever since.

Then, four years ago, even as Corning's fiber-optics business was unraveling, the company's leadership decided to place a daring bet on cleaning up diesel exhaust. That bet—which is just now beginning to play out—commits Corning to spending upward of a half-billion dollars and harnessing the talent of hundreds of researchers to develop, manufacture, and sell a line of devices to dramatically reduce pollution from diesel-powered vehicles. Diesel engines produce slightly different pollutants—including soot—than gas-powered engines, and typical car technology is ineffective against them.

"This is not a wild leap off a cliff," says Joe Miller, Corning's chief technology officer. At the same time, Miller says, it was "a very, very gutsy decision."

Corning

FY 2004 revenues: $3.85 billion
Employees: 25,000
Total sales of diesel-exhaust mitigation products in 2004: $69 million

The collapse of the tech bubble was as vivid, and as traumatic, at Corning as anywhere. Indeed, it must have appeared to blow a hole in Corning's financial performance. The company's total quarterly revenue peaked in the fourth quarter of 2000, at $2.1 billion. Just eight quarters later, in the fourth quarter of 2002, Corning's quarterly revenue was down to $736 million.

In the midst of layoffs and factory closings—only one of the five fiber-optics factories that Corning operated in 2000 remains open—the company shut down research labs in New Jersey, England, Japan, and Russia. R&D spending was cut by $5 million per week—nearly 50 percent from 2001 to 2003—affecting even Corning's storied Sullivan Park research complex. Meanwhile, diesel technology's share of the budget grew "fourfold," says Miller.

In fact, Corning didn't place just one bet on diesel antipollution devices—the market for which should grow quickly as stiff antipollution laws come into force around the world. Tom Hinman, head of diesel technologies at Corning; CTO Miller; and the Corning board made a pair of bets. The first was to build a factory to supply a market that didn't exist. The cost: $370 million. Total sales of Corning's diesel mitigation business the year the factory was approved: $12 million.

The second bet was even more daring. Corning abandoned the industry-standard filtration technology for diesel cars. As competitors scooped up business, and as construction proceeded on the new factory, Corning ordered up not just a new product from its research labs but a whole new materials-science breakthrough on which to base that product.

"We made a lonely choice," says Hinman. The existing ceramic material for diesel filters worked fine but was difficult and expensive to manufacture. Hinman's team thought it could come up with a new material that was as effective against pollution, more durable, and half as expensive for carmakers.

The company bet not just on the market—which it expects to be $1 billion a year in 2008, and to grow from there—but on its own heritage of inventiveness. In 2004, 90 percent of Corning's sales came from products less than four years old. Corning scientists have often come up with technology solutions under time and market pressure; in fact, they developed the material for catalytic converters under goading from automakers faced with the Clean Air Act of 1970. The diesel R&D group ended up taking two years to zero in on the right material for diesel-engine filters—aluminum titanate—but it checked in with senior management every six weeks, and more often when necessary. "It was tough sledding," says Hinman. "You see the competition moving on....It required tremendous confidence."

Corning is already making heavy-duty diesel-engine filters at its new Erwin, NY, plant. Production of car filters—using the new aluminum titanate ceramic—should start before year's end.

Miller came to Corning in July 2001 as CTO, and he says that cutting R&D spending was very painful—but also instructive. "There is nothing," says Miller, "like that kind of experience to temper what you're hearing, to be sure you don't just look at these things with rose-colored glasses." Even in a science-driven company, he says, "there is no algorithm to guide you on these decisions." **Charles Fishman**

AP WIDE WORLD

By Invitation Renay San Miguel

The Problem with File Sharing

After *MGM v. Grokster*, are we any closer to a solution?

Renay San Miguel is an anchor on CNN Headline News. Previously he reported on technology for CNN Headline News, CNN, CNBC, and CBS.

Late last June, in *MGM v. Grokster*, the U.S. Supreme Court ruled that file-sharing companies can be held accountable for what users do with their software. I'm not worried, however. That's because I've never used my computer to steal music.

I have reported on file sharing since the heady early days of Napster. I've interviewed many of the major players. And I've stuck a microphone in the faces of technology industry observers, who have given me their take on the financial, ethical, and societal impact of peer-to-peer networks. But I have never shared the content of my hard drive or downloaded content from others'.

I wasn't frightened of headlines like "Tech Reporter Busted in File-Sharing Crime Spree." I don't steal music for the same reason my parents didn't want me stealing comic books from the corner convenience store. Forget *MGM v. Grokster*. It's about right versus wrong. I'm a journalist; ideas and words are my currency; and I am sympathetic to other creative types, like musicians, who want to get paid for their work.

Nonetheless, I'm not inclined to believe that the Supreme Court's decision will bring religion to any of these downloading heathens. It's only six years since the dawn of Napster, but that has been long enough for many computer users to develop their own ethical standards regarding the sharing of music. And free, easy-to-use technology will always stay one step ahead of any law.

Still, I had to laugh when RealNetworks took the Supreme Court ruling and rubbed it squarely in Grokster's face. "No hassles. No lawsuits," read the full-page advertisement in the New York *Times* for Real's Rhapsody music service. The outline of a judge's gavel hovered above the words. Rhapsody offers music downloads licensed by the Recording Industry Association of America (RIAA), so its users won't be subject to lawsuits from music labels. In its 55-page opinion, the Court had criticized StreamCast Networks, the provider of file-sharing program Morpheus and another defendant in the case, for mentioning the granddaddy of all file-sharing services, Napster, in its own advertisement. That ad read, "Napster Inc. has announced that it will soon begin charging you a fee. That's if the courts don't order it shut down first. What will you do to get around it?"

Three weeks before the Court's decision, I hosted a one-hour CNNRadio special called "The Fight over File-Sharing." In one corner, representing the content providers: RIAA president Cary Sherman; Motion Picture Association of America (MPAA) president Dan Glickman; Grammy-winning country music star Clint Black; and Marilyn Bergman, Oscar-winning songwriter and president of the American Society of Composers, Authors, and Publishers. In the other corner, arguing for the right to share files: Lawrence Lessig, cyberlaw expert and the author of *Code* and *Free Culture*; rapper and producer Chuck D of Public Enemy; Adam Eisgrau, executive director of P2P United, the lobby group that includes Grokster and StreamCast; and Wayne Rosso, Grokster's former CEO.

Lessig, who argues that the existing copyright laws were written for the 18th-century printing press and not for 21st-century downloading, drew attention to a strange inconsistency in the White House's support for music producers in their case against Grokster: why would a Republican administration want to celebrate a victory for regulation? "This is a totally familiar Republican argument," Lessig said. "If you regulate in this field heavily, what you'll do is get much less innovation and investment."

But Sherman argued that the music industry wants to embrace innovation, too. Black made Sherman's case by eloquently arguing that music industry employees could lose their jobs if Black's music sales suffer because of illegal downloading. To Glickman, the whole argument was about how the movie industry could avoid the music industry's mistakes—like failing to anticipate digital downloads. The week before the radio show, the FBI, with the help of the MPAA, had shut down Elite Torrents, a website offering access to pirated movies. Glickman told me the MPAA is now starting to sue individuals, just as the RIAA has. I asked if he was concerned that for every Elite Torrents he puts out of business, two or three will take its place. Glickman answered, "You have no choice except to try to go after them, and if you go after them vigorously enough and with the help of the federal government... you at least send a strong signal that this conduct is illegal and it will not be tolerated and it will be punished."

I am not so sure it will work. I want artists and writers to be compensated for their work, but how will they ever catch the woman who recently sat next to me on a plane and watched a bootleg copy of *The Interpreter* on her laptop?

Instead of quietly alerting the flight attendant that I was sitting next to a cultural terrorist, I went back to reading my homework for the radio special: Lawrence Lessig's book, *Free Culture*. ■

STEPHANE MANEL

2005
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PARHAM AARABI, 29

University of Toronto

Sharpening a computer's listening skills

Computers have difficulty doing what the brain does easily: concentrating on one voice while ignoring other sounds. University of Toronto electrical-engineering professor Parham Aarabi created an algorithm that calculates the difference between the times at which a sound reaches two closely spaced microphones. Based on the delay, the software can determine the direction of speakers and amplify the speech of any one of them; all other conversation is reprocessed into a slight hum. Aarabi's invention, which is 30 percent more accurate than other multimicrophone systems, could filter out extraneous voices in cell-phone conversations or enhance voice control in cars.

VLADIMIR AKSYUK, 33

Lucent Technologies' Bell Labs

Making tiny mirrors for laser beams

Vladimir Aksyuk made a name for himself in the world of microelectromechanical systems in 1999 when he spearheaded the development of Bell Labs' all-optical switch—the first commercial device to use thousands of tiny rotating mirrors to intricately manipulate optical communications signals without converting them into electrical pulses and back. Its performance was 16 times faster than that of the best of its electrical counterparts.

Aksyuk has since expanded on that technology to create systems featuring arrays with mirrors as small as 100 micrometers across, each one capable of not only rotation but also up-and-down motion. These arrays enable extremely precise control of laser beams, which is crucial to the U.S. military's program to develop a secure, high-bandwidth laser communication system for aircraft, ground bases, and even space vehicles.

The arrays may also soon change how microchips are produced. The Russian-born Aksyuk is heading a project at Bell Labs to use micromirrors to carve out microchips without the costly "masks"—basically, stencils patterned with circuit designs—that are currently used to optically etch chips. Not only could this lower production costs and time, but it could also extend the lifetime of Moore's Law.

REGINA BARZILAY, 34

MIT

Teaching computers to read and write

For her doctoral dissertation at Columbia University, computer scientist Regina Barzilay led the development of Newsblaster, which does what no computer program could do before: recognize stories from different news services as being about the same basic subject, and then paraphrase elements from all of the stories to create a summary.

Though humans can easily divine the meaning of a word from its context, computers cannot. Barzilay uses statistical machine-learning software to teach computers to make educated guesses. A computer is fed pairs of text samples that it is told are equivalent—two translations of the same sentence from *Madame Bovary*, say. The computer then derives its own set of rules for recognizing matches. Once trained, it can tackle new sentences, computing "syntactic trees" that parse out their structural elements in different ways and determining the probability that each interpretation is correct. Then it statistically compares the most likely trees from

TR35 JUDGES

Howard Anderson Managing director, YankeeTek Ventures

Gordon Bell Senior researcher, Microsoft's Media Presence Research Group

***Alexis Borisy** Founder, president, and CEO, CombinatoRx

***Aref Chowdhury** Member of technical staff, quantum information and optics research department, Lucent Technologies' Bell Laboratories

Joe Chung Cofounder, Art Technology Group

James Collins Professor of biomedical engineering, Boston University

Sanjay Correa Global technology leader for energy and propulsion technologies, General Electric Global Research

Irene Greif IBM fellow and department group manager, Collaborative User Experience, IBM

Bill Joy Partner, Kleiner, Perkins, Caufield, and Byers

***Christina Lampe-Onnerud**, CEO, Boston-Power

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Nicholas Negroponte Professor of media technology and founding chairman, MIT Media Laboratory

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***Susie Wee** Principal research scientist and R&D department manager, Hewlett-Packard Labs

Chelsea C. White III Professor of transportation and logistics, School of Industrial and Systems Engineering, Georgia Institute of Technology

Jackie Ying Executive director, Institute of Bioengineering and Nanotechnology, Singapore

***Daphne Zohar** Founder and managing general partner, PureTech Ventures

**Past TR100 young innovator honoree*

two sentences to see if they match. The Newsblaster software recognizes matches about 80 percent of the time.

The software works best with news stories, because they exhibit some regularity; "the problem is more constrained," says Barzilay, now an MIT assistant professor of electrical engineering and computer science. She's working on a variation of Newsblaster for spoken language, which could yield applications that range from summarizing recorded lectures to handling airline reservation calls.

HELEN BLACKWELL, 33

University of Wisconsin

"Talking" bacteria out of causing infections

The main cause of death among cystic-fibrosis patients, and a threat to many burn victims and AIDS patients as well, is the bacterium *Pseudomonas aeruginosa*. But the microbe is not a health problem until enough of the bacteria join together to form a gooey amalgamation called a "biofilm." Almost 80 percent of bacterial infections are in biofilm form. Helen Blackwell, an assistant professor of chemistry, studies quorum sensing—the communications mechanism that tells bacteria that they have replicated enough to form a biofilm. It's easy, according to Blackwell, to synthesize the organic molecules that bacteria use to talk to each other.

Blackwell is testing a series of such messenger molecules to see if she can hijack the bacteria's communications network. So far, of the hundreds of molecules she has screened, 10 seem promising. The right molecule might fight a hard-to-treat infection or induce a small, early infection to stimulate the body's immune response. Blackwell's group developed a way to speed up the reaction that produces the messenger molecules by heating it with microwaves. "We reduce a reaction sequence from about three days to about 45 minutes," she says.

THIJN BRUMMELKAMP, 30

Whitehead Institute for Biomedical Research

Silencing the genes that cause cancer

Amassing detailed information about which human genes play a role in cancer and what their roles are is central to many efforts to fight the disease. One of the most promising new approaches to the identification of cancer-causing genes is called RNA interference, a method for suppressing genes to learn their functions. But RNAi is costly, and silences genes for only a few days at a time—not long enough for researchers to study slow-developing diseases. Thijn Brummelkamp has developed an inexpensive way to make the effect last, silencing a single gene indefinitely. Brummelkamp's work "will lead to new treatments" for cancer, says MIT biologist and Nobel laureate Phillip Sharp.

MARTHA BULYK, 33

Harvard Medical School

Discovering how genes are regulated

Figuring out how genes coördinate the complex phenomena of life involves more than deciphering a DNA sequence. Proteins called transcription factors control genes by attaching to DNA; discovering where each of these proteins binds is critical to understanding how genes regulate working cells. Martha Bulyk has taken the gene chip technology originally developed to measure gene activity and adapted it to determine the DNA binding preferences of proteins. The technology replaces painstaking assays with efficient screens, which could aid research on diseases that are affected by mutations in transcription factors or in their binding sites, such as hypertension, cancer, and diabetes.

STEWART BUTTERFIELD, 32

Flickr (Yahoo)

Building communities through photos

In February 2004, Stewart Butterfield and his coworkers at Ludicorp, then engaged in developing an online game, launched a side product called Flickr—"kind of on a lark." By summer, the project had taken over the company; today it's the Web's fastest-growing photo-sharing site. Employing "tags" that allow people to make their photos searchable by content, Flickr encourages users to engage in discussions about their pictures. Acquired by Yahoo in March, Flickr now has more than one million users, who post hundreds of thousands of new photos a day.

GEORGE CANDEA, 30

Aster Data Systems

Protecting software from crashes

As counterintuitive as it might seem, George Candea's "crash-only software" concept may actually help keep software crash free. According to Candea, software crashes and subsequent reboots needn't be catastrophic, systemwide events. He has described software that can be trained to monitor itself and, if it detects something amiss, to launch a surgical, or "micro,"

reboot of just the problematic application element, while the system as a whole functions uninterrupted. "Microrebooting allows software to react to failure in machine time as opposed to human time," says Candea, who recently got his doctorate in computer science at Stanford University.

BRYAN CANTRILL, 31

Sun Microsystems

Tracing software in real time

Even with all the recent advances in information technology, systems administrators are still running blind: if a piece of software doesn't quite do what it should, administrators may spend days hunting down the problem and figuring out how to fix it. Bryan Cantrill, senior staff engineer at Sun Microsystems, has created an application called DTrace that offers real-time software diagnostics—giving IT folks a way to see what's going on and start improving performance in minutes. This kind of power elates many programmers. "With DTrace," says Cantrill, "I can walk into a room of hardened technologists and get them giggling."

ANDY CARVIN, 34

Digital Divide Network

Bringing Internet power to the have-nots

As founding editor in 1999 and current director of the Digital Divide Network, Andy Carvin has helped build an online community of more than 7,500 technology activists, educators, small-business owners, and policy makers. Their mission is to devise remedies for the fundamental information-age inequity: most people in the world lack the ability to access the Internet or the skills to use it. Carvin is also promoting a way for technology to give voice to the disenfranchised: mobcasting.

Carvin's idea is to combine the ubiquity of cell phones with the ease of posting information to Web logs (blogs). Say protesting human-rights activists get roughed up by police, with no traditional media on hand to record their plight. Over their phones, the human-rights activists could send multiple reports on what's happening—either audio or video—to the same website. Carvin is pushing programmers to create mobcasting software that works outside the U.S. phone system. With the use of mobcasting, suggests Carvin, "suddenly, the very people who are victims are empowered to bear witness to the world almost instantaneously."

BRAM COHEN, 29

BitTorrent

Upending the file-sharing world, bit by bit

Bram Cohen's creation, BitTorrent, answers a deceptively simple question: if someone requests a file over a network, and multiple people on the network possess the file, why should only one person send the file in its entirety to the requester? Cohen's revolutionary solution: send tiny chunks of the file from multiple users, eliminating the bandwidth crunch that results when a single user sends a large file in its entirety. A 400-megabyte video file that could take hours for a single user to distribute can be broken up into thousands of pieces, each of which takes only a few seconds to send. The impact of the technology that Cohen developed goes far beyond the world of illicit file-swapping: game companies and Linux developers are now experimenting with BitTorrent distribution as well.

Cohen is humble about his creation and its potential impact. It is, he says, "just a way to move bits around."

DANIEL RISKIN, 33

UCLA Medical Center

Developing devices for wound closure and early heart-attack intervention

In addition to working about 80 hours a week as a surgical resident at the University of California, Los Angeles, Medical Center, Daniel Riskin is building companies to develop and market new medical devices. "Physicians have an obligation to innovate," says Riskin.

While training to be a doctor at Boston University and Tufts University, Riskin dabbled in technology development, writing software to help physicians manage their practices and researching different designs for surgical clips with a medical-device company. But he wanted to do more—to come up with his own inventions and bring them into widespread use. Thus he enrolled, partway through his residency, at MIT's Sloan School of Management. While studying for his MBA, he kept up his operating-room skills by working at private surgical practices on evenings and weekends.

After graduating from Sloan, Riskin was named the first fellow in Stanford University's new surgical-innovation program. At Stanford, he and his collaborators developed an elastic, adhesive, polymer-based patch that they hope will provide a less painful alternative to staples or stitches as a way to close up wounds and surgical incisions. He is now forming a company to commercialize the patch, which he expects will also reduce scarring.

Riskin also helps doctors with few business skills or little experience to become innovators themselves.

Last year, Riskin, along with Michael Laposata, director of clinical laboratories at Massachusetts General Hospital in Boston, started a company, MedPacks, to develop portable diagnostic tests and medications that patients could use at home—before getting to the emergency room—if they thought they were having heart attacks. Such early treatment could lower the risk of death or complications by as much as 50 percent. "If we're going to do anything innovative," says Laposata, "we're going to need more Dans."

BRAD SWONETZ (RISKIN); AP PHOTO/KEVIN P. CASEY (COHEN)

JIA CHEN, 33

IBM Watson Research Center

Looking past silicon to carbon nanotubes

Eventually, semiconductor manufacturers won't be able to cram any more transistors onto silicon chips. So Jia Chen is working on an alternative: electronic circuits and devices that use cylindrical, nanometer-wide carbon molecules called carbon nanotubes. Among their other advantages, some types of nanotubes can conduct electricity 100 times better than silicon.

So far, most transistors made out of carbon nanotubes have been *p*-type, meaning they use positive charge carriers; negative—*n*-type—nanotube transistors have been much more difficult to produce. Chen, however, has found a simpler way to make them, which could be an important step toward integrating carbon nanotubes into conventional electronics. Chen discovered that attaching certain kinds of molecules to nanotubes would add electrons to them or draw electrons out, yielding either *p*- or *n*-type devices.

Another problem with nanotube transistors is their need for metal electrodes, which are necessarily much larger than the nanotubes. The size difference tends to cause current leakage, reducing electrical efficiency. Chen found she could add certain impurities to a small segment of a nanotube to allow the nanotube to serve as an electrode, but one with little leakage. Her nanotube transistors carried 100 times as much electrical current as previous ones.

The properties of nanotubes vary depending on their diameters. Choosing a particular diameter causes a tube to emit light at a particular wavelength. Chen was able to control the positive and negative charges in a nanotube to make it emit light 100 times brighter than the light from earlier devices. This could give nanotubes the ability to serve as optical interconnects—transmitting data among circuits more efficiently than copper does. Eventually, every device on a chip could be made from nanotubes. "Imagine a circuit with the same material acting as sensors, transistors, light emitters, and also interconnects," says Chen.

DENNIS KLEIMAN (CHEN)

DENNIS CROWLEY, 29

Dodgeball

Moving online socializing into the streets

When Dennis Crowley goes out clubbing in New York, he'll text a message with his location to Dodgeball, the company that he founded. Crowley's message—"@ Luna Lounge," for example—goes out to all the friends he has listed at the Dodgeball website. The company's computer checks the club's address against its list of geographical locations in 22 cities. If someone who is not on Crowley's friend list but is on the list of one of his friends has checked in within the last three hours and a 10-block radius, the computer notifies both parties. If Crowley has listed a girl he doesn't know as a "crush," she'll get a message with his picture saying he's interested. She'll have the option to find him or dodge him, without his ever knowing where she is. Google liked the idea so much it bought Dodgeball in May. Crowley says it's "a very powerful thing to know where your friends are all the time."

MATTHEW DeLISA, 32

Cornell University

Delivering more medicine from microbes

Each year, billions of dollars' worth of drugs, from insulin for diabetics to the stroke drug tPA, are made in huge vats full of microbes engineered to produce human proteins. The process is both inefficient and enormously expensive. Matthew DeLisa, an assistant professor of chemical and biomolecular engineering, was the first scientist to use a twin arginine translocation (Tat) pathway to produce human proteins. This should mean cleaner proteins and longer-lived cultures.

DeLisa is also modifying bacteria to improve each step in protein production. His focus, he says, is "the engineering of biological machines to tackle problems that nature itself can't do." Until recently, the biotech industry focused on changing the growth environment for bacteria to boost protein productivity, but DeLisa is supercharging production by going inside the cell itself. For example, he's replacing key parts of the bacteria's protein-making machinery with components from higher organisms to produce finely tuned miniature drug factories.

KEVIN EGGAN, 31

Harvard University

Using cloning to study degenerative diseases

While earning his PhD, Kevin Eggan helped make Rudolf Jaenisch's lab at the Whitehead Institute for Biomedical Research a preëminent cloning lab. Eggan became "arguably the most skillful mouse cloner in this country," says Jaenisch. Eggan used those skills to clone mice from neurons, proving that animals could be cloned from even the most specialized cells in the body—a feat that many scientists considered impossible. Eggan also helped explain how cloning "reprograms" the genetic material from an adult mouse cell, identifying the changes that take place to reset the nucleus to the beginning of development.

Eggan, now an assistant professor of molecular and cellular biology, plans to create human stem cell lines from patients with neurodegenerative disorders such as Parkinson's and Lou Gehrig's diseases, in order to study disease development and search for new drugs. He has also begun studying nuclear reprogramming in human cells in the hope of finding a way to create patient-specific embryonic stem cells without using human eggs.

ANITA GOEL, 32

Nanobiosym

Building novel pathogen detectors

Physicist and physician Anita Goel finds inspiration in the tiny: the proteins that inch their way along DNA, reading and copying the genes inside every cell. As a physics graduate student at Harvard University, Goel developed a theory to explain how these molecular motors work. While working on her medical degree at Harvard in 2004, she founded Nanobiosym to apply her theories to the development of nanotech devices for precisely controlling these proteins; such devices could identify viruses and bacteria in, say, a blood sample more rapidly, accurately, and cheaply than current techniques can. Her goal: a low-cost, handheld device for biodefense and biomedical applications.

SAUL GRIFFITH, 31

Squid Labs

Following inspiration for inventing

Before Saul Griffith perfected his five-minute method for making custom-crafted lenses for $5, he volunteered in South America, where he once had to hand a pair of dainty granny glasses to a six-foot-tall man: they were the only pair the volunteer group had that fit the man's prescription, he recalls. And it was from kite-surfing, a sport that relies on the strength of the ropes tethering a surfer to a wind-drawn parachute, that Griffith drew the idea for smart ropes, in which embedded conductive threads reveal developing weaknesses. After pursuing such ideas en route to his doctorate at the MIT Media Lab, he cofounded Squid Labs to explore the business of inventing. Among his projects: "open source hardware," to do for computer equipment what Linux did for operating systems.

PAUL HERGENROTHER, 33

University of Illinois at Urbana-Champaign

Discovering drugs that defy convention

Paul Hergenrother is a chemist who takes on huge, unsolved medical problems: antibiotic resistance, cancer, and neurodegenerative disease. His small-molecule compounds bind tightly to unconventional disease-related targets, deactivating them. For example, Hergenrother found compounds that eliminate plasmids, the DNA rings that deadly bacteria use to spread antibiotic resistance. That pioneering project led him to a general method for finding drugs that target a particular type of RNA—messenger RNA—as a way to silence disease-causing genes, something standard drugs can't do. Hergenrother's "ten-year vision" could lead to treatments for Alzheimer's and Parkinson's.

KATRINE HILMEN, 34

ABB Corporate Research

Getting the most out of oil rigs

Katrine Hilmen is helping to keep dwindling North Sea oil fields productive. The chemical engineer at ABB's research center pursuing such ideas en route to his doctorate at the MIT Media Lab, he cofounded Squid Labs to explore the business of inventing. Among his projects: "open source hardware," to do for computer equipment what Linux did for operating systems.

NARASIMHA CHARI, 31

Tropos Networks

Setting the mesh networking standard

In the late 1990s, when Wi-Fi-equipped laptops were still a novelty, Narasimha Chari saw the possibility of creating large communications infrastructures using wireless mesh networks—which at the time were the exclusive province of the military. In 18 months of moonlighting while a physics grad student at Harvard University, he created elegant algorithms that tailored mesh networking for routine civilian communications.

Tropos Networks, the company Chari founded in 2000 with coinventor Devabhaktuni Srikrishna, helped launch commercial wireless mesh networking. With their straightforward installation—routers attach to lampposts—and attendant low cost, mesh networks have eased into plentiful use both outdoors (on campuses, in public safety networks, and at gatherings such as festivals) and in (in hospitals and factories). But Tropos is focusing on the rapidly growing market for networks that serve entire municipalities. That's the application of choice for one-third of the company's 200 customers.

Tropos's services, which are built around Chari's routing protocols, dominate the nascent mesh-networking industry. Telecommunications companies fear the proliferation of the technology, seeing it as a threat to their Internet access businesses. In fact, the telecommunications industry is lobbying for legislation granting them—not local governments—first dibs on municipal Wi-Fi installations. Meanwhile, Tropos is gaining customers at a rapid clip; 75 signed on in the first half of 2005.

Tropos's expansion is bringing Chari full circle. In 1992, after receiving the third-highest score out of 80,000 on the Indian Institutes of Technology entrance exam, Chari left India for Caltech. Later, while at Harvard, he had late-night talks with Caltech pal Srikrishna about providing anytime, anywhere communications in developing countries. Now, as Tropos ships its first systems to India, Chari is seeing his innovation connect back to his homeland.

ANDREW NAGATA (CHARI); MARK RICHARDS (GRIFFITH)

ter in Norway developed innovative online monitoring and management tools for oil production platforms. Her technology monitors parameters such as heat, vibration, pressure, and flow rates, and can quickly identify a problem and its cause. The typical benefits: a 3 to 8 percent increase in oil production, a 10 to 15 percent reduction in operating expenses, and less pollution. Her innovations in process optimization, which have led to four patent filings, are widely studied by others in the field, enhancing their impact.

TRACEY HO, 29

Caltech

Scrambling bits for a more efficient Internet

Today's Internet transmissions chop files into packets, each of which is passed from router to router until it reaches its final destination. But when files get big or are sent to many users, transmitting them without clogging the network becomes complicated. With "network coding," an idea first proposed in 2000, routers would jumble together the bits from different packets, forming new packets. Recombining the data in this way gives the end user additional information, theoretically speeding downloads and increasing network capacity. But early network coding schemes required a godlike central authority that knew how the packets were to be combined—a practical impossibility.

As a PhD student at MIT, Tracey Ho had a novel alternative: let network nodes mix packets together at random, tagging them with just enough information to help end users' computers recover the original data. This decentralized method automatically optimizes bandwidth use. "It sounds kind of insane," says Muriel Médard, Ho's PhD advisor. "But it's not just that it works; you can't make it work better." As an assistant professor of electrical engineering and computer science, Ho still studies network coding. But only months after she first presented her "distributed random network coding" scheme, Microsoft researchers showed that it can clearly outperform today's multicast systems. The company has embarked on a project called Avalanche to commercialize the scheme.

TREY IDEKER, 33

University of California, San Diego

Defining and advancing systems biology

As a graduate student, Trey Ideker published a paper that helped define the discipline of systems biology. His research goals today reflect those of the entire field: to integrate the myriad data that researchers can collect about a cell into coherent computer models. As an assistant professor of bioengineering, Ideker is not only improving these models but employing them in biological discovery. For instance, he is looking for protein networks uniquely present in pathogenic organisms; these could make good drug targets. He hopes that, ultimately, systems-derived models will let researchers simulate how potential drugs will affect the body—long before the compounds are tested in humans.

HANG LU, 28

Georgia Institute of Technology

Designing microfluidic chips to study cells

Hang Lu has a flair for adapting to new environments. At 16, she moved from China to Colorado, where she excelled academically. As a postdoc, she applied her expertise in building bioMEMs—tiny devices that manipulate cells and microörganisms—to devising innovative experiments in neurobiology. Lu has designed minute mazes to test how microscopic worms learn using smell, and she constructed microscale gas gradients to help identify the sensory pathways that the worms use to detect oxygen levels. Now an assistant professor of chemical and biomolecular engineering, Lu hopes her continued worm work will yield clues to the workings of the human brain.

SAMUEL MADDEN, 29

MIT

Simplifying wireless sensor nets

Wireless sensor networks enable the remote monitoring of everything from the habitat of an endangered bird species to a building's response to an earthquake. The problem, says computer scientist Samuel Madden, is that proper programming of the nets' data-gathering "motes" can require months of expert attention. In 2003, while a graduate student at the University of California, Berkeley, Madden created software called TinyDB that translates high-level queries like "What's the average temperature in the forest?" into precise instructions. Madden, an assistant professor of computer science, is now installing sensors in cars to monitor operating conditions and figure out faster routes.

YAEL MAGUIRE, 30

ThingMagic

Inventing across disciplines

A technological omnivore, Yael Maguire moves fearlessly among fields such as physics, engineering, biology, and soft-

RICHARD SCHULTZ (MAGUIRE)

ware design. As a graduate student at MIT, he designed a sensor that makes the measurement of nuclear magnetic resonance between 10 and 100 times more sensitive but works on samples 1,000 to 10,000 times smaller than those required by current probes. Shuguang Zhang, associate director of MIT's Center for Biomedical Engineering and Maguire's thesis advisor, says the sensors will allow researchers to more easily obtain information valuable for designing new drugs.

While a doctoral student at the MIT Media Laboratory, Maguire cofounded ThingMagic, where he is now co–chief technology officer, and pioneered the use of software-defined radio for the radio frequency ID chips that help track retail inventory more quickly and accurately. Maguire's software allows a single reader to scan and decode hundreds of tags at once, no matter which of the many existing data protocols they use. Maguire also cofounded ThinkCycle, a nonprofit that encourages technologists to collaborate on problems in developing countries.

MELISSA MAHONEY, 32

University of Colorado at Boulder

Making materials to treat brain damage

Nerve cell transplants offer tremendous promise for patients who are suffering the effects of stroke, or from Parkinson's disease or other neurodegenerative illnesses. But experiments in rodents showed that about 95 percent of cells transplanted into the brain die before they can help the recipient. Melissa Mahoney is working to develop hydrogel materials that can house the cells, protecting them and supplying them with proteins that encourage their growth. In collaboration with scientists at the University of Colorado at Denver's Health Sciences Center, Mahoney, an assistant professor of chemical engineering, plans to test these cell-loaded gels in rats within the next year.

RAJIT MANOHAR, 33

Cornell University

Taking the clocks out of computer chips

The different functions of a computer chip are synchronized by an onboard clock, but that means the fastest operations can't pass on their data until the slowest have finished. Rajit Manohar, an associate professor of electrical and computer engineering, speeds up chips and lowers power consumption by removing the clock; his chips are 10 times more energy efficient than previous clockless chips. Instead of a separate clock network carrying a global timing signal, Manohar's chips use short wires to carry signals that alert successive operations when the previous operations have finished. Last year, Manohar also built the first low-power processor for sensor networks: "You only activate the part of the chip that's doing the work you need," he says. Such sensors could run on the same batteries for years instead of weeks.

DAVID PENNOCK, 34

Yahoo Research

Predicting the future of markets

How could markets possibly be able to predict things like where a hurricane will strike? In part because they aggregate information well, says David Pennock, who studies how economic theory can be expressed via computation. Pennock's research underlies not only predictive markets but also the enormously successful sponsored search functions featured on Yahoo, Google, and elsewhere. Recommendation engines like those on Amazon .com also draw from Pennock's work. Most recently, Pennock designed a new type of market, the "dynamic pari-mutuel market," now being offered at Yahoo Tech Buzz. Part horse racing, part futures market, it lets people bet on whether a product is a fad or for real.

MATTHEW RABINOWITZ, 32

Rosum

Giving GPS a sharper image

Inside buildings and the urban valleys of large cities, Global Positioning System technology is often inaccurate or unusable. Matthew Rabinowitz has sharpened GPS precision by exploiting the synchronization codes embedded in broadcast television signals. These codes allow a TV receiver to compile numerous signals into a single harmonious output. Rabinowitz, who cofounded Rosum and now serves as chief technology officer, has developed a handheld device that uses sync codes to calculate how far the user is from the source of the signals and thus determine his or her location. The Rosum technology refines GPS position readings to within a meter or two, even indoors and in cities.

ADAM RASHEED, 31

GE Global Research

Pulsing the way to efficient aircraft engines

Adam Rasheed has made fundamental improvements to an aircraft propulsion system based on a pulsed-detonation engine—a technology in which a fuel-air mixture is compressed and exploded as many

as 100 times per second. Pulsed detonation creates vastly higher pressures than the slower burn of a conventional engine's combustion chamber, offering a theoretical 5 percent efficiency gain. Rasheed built a prototype that operates longer and without the oxygen enrichment required by other research efforts. And he was the first to use such technology in an important role: to drive the turbines that are at the heart of today's jet engines.

SHILADITYA SENGUPTA, 33

Harvard Medical School

Delivering drugs to cancer cells

As a master's student in India, Shiladitya Sengupta developed an anti-inflammatory gel that's now sold in India under the brand name Nimulid. During his doctoral studies at the University of Cambridge, he revealed how a protein that causes liver regeneration promotes blood vessel growth, and cofounded Dynamic Biosystems to turn the discovery into treatments for chronic wounds such as pressure sores. But a child's toy—several small balloons encapsulated in a bigger one—inspired what may be his greatest innovation: a nanoscale device to treat cancer.

Sengupta's drug delivery device, developed during his postdoc at MIT, consists of a lipid sphere about 200 nanometers wide surrounding smaller, biodegradable polymer spheres. These nanocells home in on cancers based on the unique characteristics of tumor blood vessels. The outer shells then dissolve, releasing a drug that destroys the vessels. As the cancer cells starve for oxygen, they secrete enzymes that break up the inner spheres, dispensing a standard chemotherapy agent. The nanocells have the potential both to treat tumors more effectively than existing regimes and to reduce side effects.

The nanocells have proved effective in mouse models of melanoma and lung cancer. Because Sengupta designed them using polymers and drugs already approved for human use, doctors can quickly move them into clinical trials. Now an assistant professor at Harvard Medical School and Brigham and Women's Hospital, Sengupta is extending the concept to treat other diseases.

FRANCESCO STELLACCI, 32

MIT

Fabricating microarrays faster

Microarrays are slides dotted with hundreds of thousands of different gene segments that help researchers spot particular DNA sequences—making microarrays invaluable tools for the study of genetically influenced diseases ranging from diabetes to many forms of cancer. But current methods for manufacturing microarrays are very costly and time consuming because of the dozens of printing steps they require. Materials science assistant professor Francesco Stellacci may have found a way to quickly produce microarrays for as little as $50. In his approach, a single strand of DNA "stamps" genetic information into a slide, which can then serve as a master template for the production of multiple identical arrays.

ADAM STUBBLEFIELD, 24

Johns Hopkins University

Unlocking digital doors

Adam Stubblefield has become a champion at finding holes in supposedly secure systems. He proved that an early version of the wireless security protocol WEP was not secure, and helped crack the Secure Digital Music Initiative's electronic watermark. Stubblefield also helped reveal security flaws in Diebold's voting machine software—the first serious security review of the electronic-voting-machine's code, according to Cindy Cohn, legal director of the Electronic Frontier Foundation.

Most recently, Stubblefield reverse-engineered a radio frequency ID cipher. Yet he modestly notes he's not much of a programmer and has yet to learn to speak a foreign language. "My brain isn't very good at many things," says Stubblefield, who received his doctorate from Johns Hopkins in the spring. But his brain is helping keep information systems from being used to encroach on civil liberties—a good thing indeed.

HAITAO ZHENG, 30

University of California, Santa Barbara

Tuning in "cognitive radios"

At 15, Haitao Zheng stood out at China's competitive Xian Jiaotong University for both her youth and her brilliance. Today, her work on so-called cognitive radios stands out for its potential to make a promising technology practical. Using software, cognitive radios dynamically detect and exploit unused radio frequencies; the devices could alleviate competition for the ever shrinking amount of unassigned radio spectrum. To be truly useful, though, a cognitive radio must not only detect free spectrum but also select the best frequency for a given function, all without interfering with other devices. At Microsoft Research Asia, Zheng created algorithms that allow disparate devices to "negotiate," automatically allocating the available spectrum efficiently and fairly. Zheng is continuing her research on open spectrum systems as an assistant professor of computer science at the University of California, Santa Barbara.

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Killer Maps

Google, Microsoft, and Yahoo are racing to transform online maps into full-blown browsers, organizing information—and, of course, ads—according to geography. The likely winner? You.

By Wade Roush

SAY YOU'RE A FAN OF PAUL CÉZANNE, AND YOU'VE DECIDED to fly to the Windy City to see his masterpieces at the Art Institute of Chicago. The only problem: you've never been to Chicago and have no idea where the Institute is or where to stay or eat.

No worries. You fire up Google Earth on your PC (it's a free download at earth.google.com) and enter "Art Institute of Chicago" in the search box. Off to one side of the screen, a traditional list of search results appears, with the Art Institute at the top. But the real action is in the central window, where Google Earth's virtual camera zooms from an orbital view of North America down to a satellite image of downtown Chicago. You click on the top listing in the search results, and a balloon pops up over the image, indicating the Institute's building and giving its street address, a Web address, and a link to driving directions.

You plan to rent a car at O'Hare International Airport and drive to the museum, so you click on the "directions" link. Once you've entered your starting point—in this case, ORD, for O'Hare—the camera zooms out a bit and shows a colored line marking your route. Turn-by-turn instructions appear on the left. You'd like to rehearse the drive, so you click the play button for an animated preview: the camera swoops down to a one-kilometer altitude and flies along the entire route, which turns out to be an easy 27-kilometer trip along I-90 and a few surface streets.

You still need a hotel, so you click on the "Lodging" check box. The map fills with options, and you spot a Crowne Plaza just around the block from the Art Institute. The hotel's balloon leads you to Google Local, which displays the hotel's location on a standard Google map and gives links to customer reviews, summaries from Frommer's and other travel guides, and sites where you

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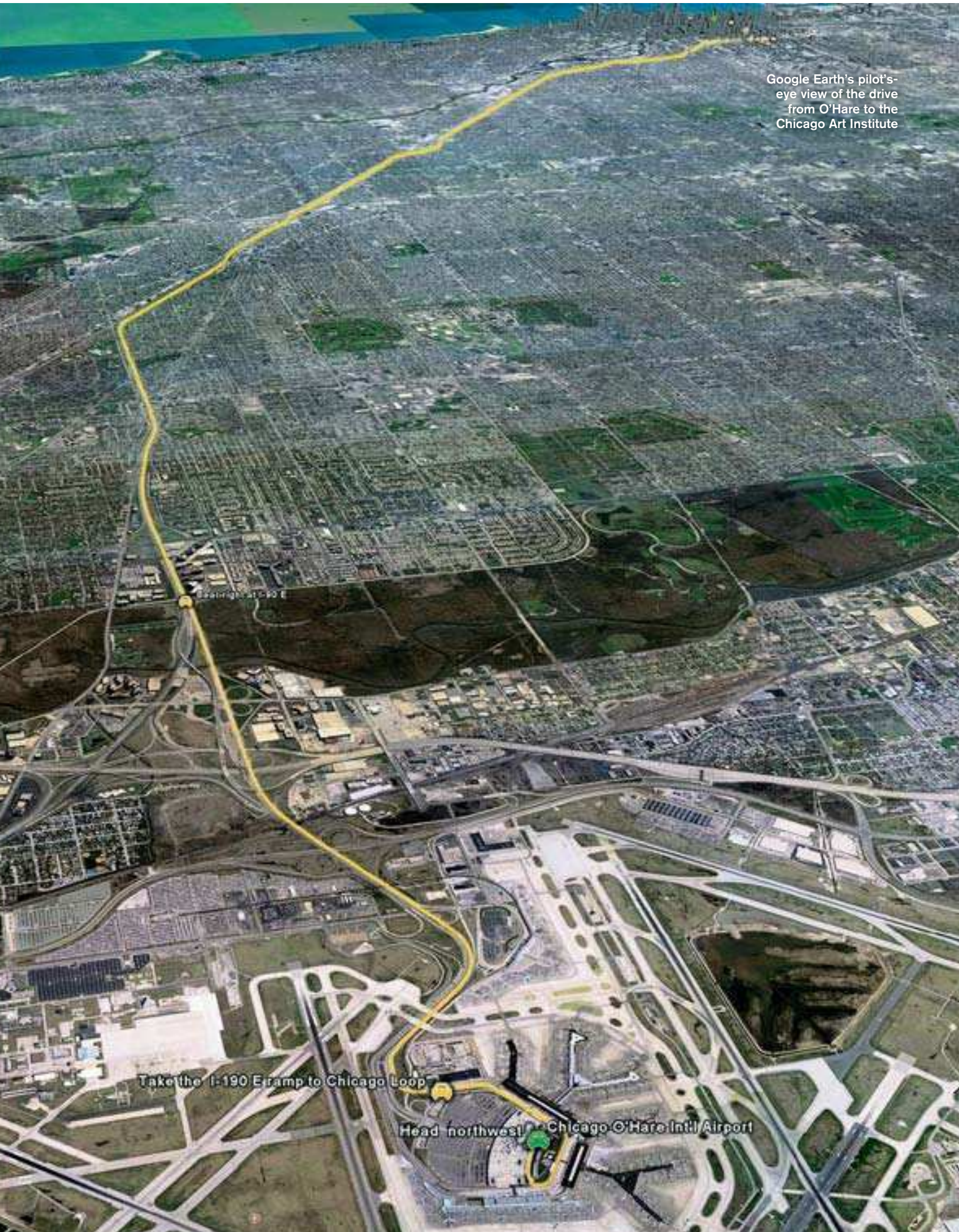
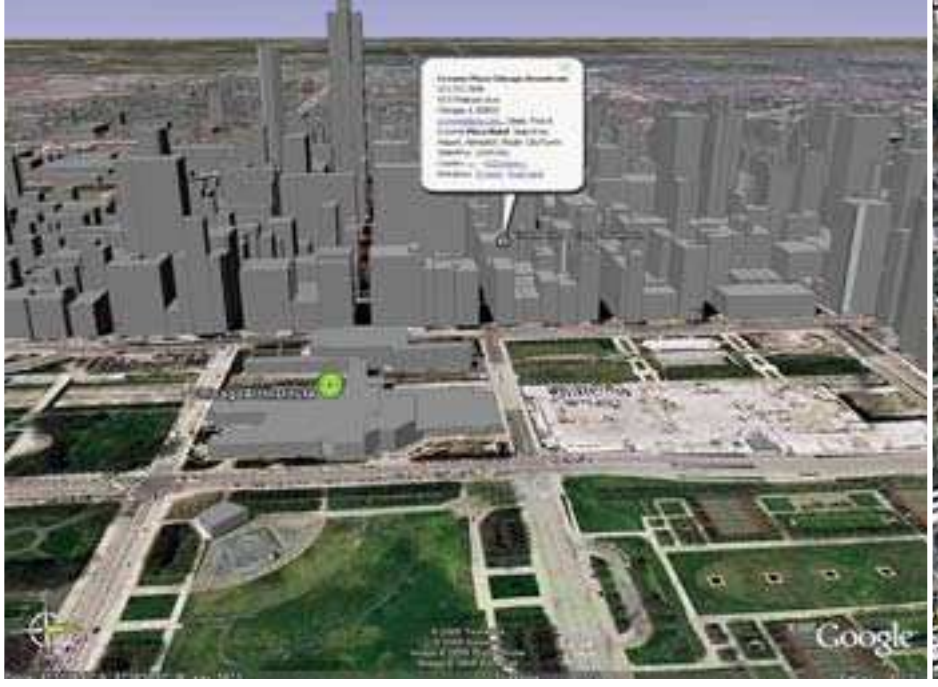


Google Earth's pilot's-eye view of the drive from O'Hare to the Chicago Art Institute



can book a room. You reserve a room and go back to Google Earth. Now you can search for restaurants by clicking on the "Dining" box—or you can click on "Buildings" to get a 3-D view of Chicago's cityscape. You notice that the Sears Tower is about eight blocks from your hotel; being an architecture buff, you add the 103rd-floor Skydeck to your sightseeing agenda.

You want to see what the area around the institute really looks like, so you leave Google Earth for a moment and visit geobloggers.com. There, you can use Google maps to search the popular photo-sharing site Flickr for shots that have been "geotagged," or encoded with latitude and longitude information. On a Google map of downtown Chicago, you now see numerous pushpin-like place markers; as you click on each one, a balloon appears with a thumbnail image linking to Flickr.

Finally, you're wondering how safe the area is at night. You leave Google Earth for a moment and visit chicagocrime.org, a free site that uses Google maps to show the locations of crimes reported to the Chicago Police Department. You zoom in on the intersection of Wabash and Madison, near your hotel. A handful of incidents show up on the map. You decide that caution is in order, but that there's no reason to be paranoid. When you finally get to Chicago, you'll be fully prepared—and you'll be able to view Cézanne's azure Mediterranean seascapes and luminous still lifes with a clear mind.

Read/Write Maps

There was a time, not very long ago, when the best way to prepare for a trip like this one was to order one of AAA's custom TripTiks, map flip-books in which actual humans traced AAA's recommended routes by hand with highlighter pens. You can still order a hard-copy TripTik, but since the mid-1990s it's been faster to build it yourself on the association's website or visit a site such as MapQuest. And now consumers have access to advanced geographical visualization tools such as Google Maps, launched by the search giant in February, and Google Earth, released in June. With their combination of detailed aerial and satellite maps, high-powered graphics and animation, comprehensive local search functions, and hackability—it's child's play for programmers to display their own data atop Google maps—the new programs make paper maps and previous generations of online mapping tools seem primitive.

"I describe it as a browser for the earth," John Hanke, general manager of Google's Keyhole group, says of Google Earth. Keyhole, where Hanke was CEO until Google acquired the company last year, developed the software upon which Google Earth is based, mostly for customers in defense, engineering, and real-estate investing. Now that Keyhole is part of Google, the idea is to use geography as a fundamental structural principle for the entire Web. "The interesting part is not necessarily the core map but the information from the Web that's now being organized geographically, so that you can get to it and understand it in its proper context," says Hanke.

It's such a potentially lucrative idea, in fact, that Microsoft has followed suit, introducing its own search-and-mapping service called MSN Virtual Earth. The service offers satellite photos, zooming and panning abilities, and interactive search listings resembling those of Google Earth, but it may actually reach a wider audience than Google's product, since it runs inside a browser window rather than needing to be downloaded as a separate application. Yahoo, too, is in the game: last year it introduced maps that provide, say, the locations of all the coffee shops with Wi-Fi hot spots within a particular neighborhood.

Crucially, each company has released instructions for outside programmers—called application programming interfaces (APIs)—that let them build online services that tap into the company's own map programs. Developers are taking advantage of the new APIs to put out geospatial applications such as geobloggers.com and chicagocrime.org. The fact that these "mash-ups" are so easy to make is giving rise to a community of mapmakers and map users who are busy geotagging every piece of place-related information they can put their hands on. And the more information on the Web that's tied to geographical coördinates, the better the results—and the better targeted the ads—that can be served up in response to location-driven searches.

The mapping revolution could, in short, change the way we think of the World Wide Web. We've long spoken of the Web as if it were a place—with "sites" that we "go to"—but as places go,

Left to right: Peer inside Beijing's Forbidden City; plan a vacation using Google Earth's digital model of Chicago; check out a prospective neighborhood before the realtor takes you for a ride; survey a Danish wind farm; bone up on Roman history before swinging by the Colosseum.

it's been a rather abstract, disembodied one. Now that's changing. Geotagging means the Web is slowly being wedded with real space, enhancing physical places with information that can deepen our experiences of them and making computing into a more "continuous" part of our real lives *(see "Social Machines," August 2005)*. For example, users of smart phones and wireless PDAs with location technologies such as Global Positioning System chips may soon be able to automatically retrieve stories, photos, videos, or historical accounts related to their current locations, along with ads and listings for nearby shopping, dining, entertainment, and business outlets.

And the information is already flowing both ways: users can upload their own texts, photographs, and other data to the Internet and pin them to specific latitudes and longitudes. "Historically, maps were a 'read-only' medium," says Schuyler Erle, chief engineer at Locative Technologies and coauthor of *Mapping Hacks*. "Maps were only created by professional cartographers and professional GIS [geographic information systems] people. What has happened because of Moore's Law is that people now have the computing power on their desktops to manage the vast amounts of data that are required for digital cartography. Maps are increasingly a 'read-write' medium. That changes how we interact with them and the impact they can have on our everyday lives."

Many details of the emerging geospatial Web have yet to be worked out. No one knows which location-finding technologies are right for consumers or which will be endorsed by cellular carriers and device makers. Only a few of the U.S. cellular networks currently sell phones with GPS chips, and only one, Nextel, actually makes its phones' GPS functions accessible to software developers. Outside North America, the mapping revolution may take longer, since some foreign governments maintain strict control over map data or charge exorbitantly for it.

But none of that is damping excitement in the community of Web developers and e-commerce managers. In June, more than 500 executives, programmers, and professionals, including some from traditional GIS companies such as San Diego's Environmental Systems Research Institute (ESRI), converged on San Francisco for Where 2.0, a new conference organized by tech-book publisher O'Reilly Media. Participants spent two days admiring one another's latest mapping creations and strategizing over how to convert geographic information delivered over the Web into actual transactions—from simply clicking on an advertisement to buying a house.

Within hours of Google Maps' release, programmers had reverse-engineered it, making their own content appear in the info windows.

Trailblazing

How did such advanced mapping tools wind up in the hands of average Web users? The short answer starts with the U.S. Department of Defense's 1978 launch of the first satellites in the Global Positioning System. A GPS receiver determines how long the time signals broadcast by several GPS satellites have taken to reach it and, with a bit of spherical geometry, can then calculate its position to within a matter of meters. The original use of the system was to allow U.S. missile submarines to determine their positions within a few minutes of surfacing—information required by the guidance systems in the subs' ICBMs if they were to make direct hits on enemy missile silos.

Beginning during the Reagan administration, civilians could also use GPS, but only in a degraded form, accurate to about 100 meters in any direction. On May 1, 2000, the intentional degrading of GPS signals, called Selective Availability, was turned off by order of President Clinton, instantly reducing the range of error in a civilian GPS fix to 10 meters or so. This sudden and enormous increase in the accuracy of GPS location-finding set the stage for all the online mapping innovation that has followed. It spurred a broad group, including hikers, hackers, and urban planners, to take a deeper interest in Web-based maps, which were a natural way to publish the new geo-

graphic data they could collect and share using their GPS units. After all, a consumer-grade GPS receiver could now distinguish between one side of a street and the other, determine which storefront a user was walking past, or guide someone to a hidden "geocache" using only its published latitude and longitude *(see "Roamin' Holiday," September 2005)*.

Unfortunately, when it came to making online maps, there weren't a lot of options to choose from. Since its launch in 1996, one website—MapQuest—had dominated this niche. And while many Web developers wrote programs that copied MapQuest maps for redisplay in other contexts, they couldn't program more sophisticated tricks, such as overlaying their own data on MapQuest maps. "The first-generation Web services in the mapping space—ESRI, MapQuest, MapPoint—have had APIs for quite some time, but they weren't hacker-friendly," says Tim O'Reilly, CEO of O'Reilly Media and creator of the Where 2.0 conference. Eventually, MapQuest prohibited even the repurposing of its maps. This created a demand for reusable map data, a demand that would eventually be met by companies such as Google, Yahoo, and Microsoft.

Along the way, however, a few other things had to happen. First, computers needed enough processing speed and storage capacity to handle the multigigabyte data sets and complex mathematical transformations that displaying and manipulating digital maps require. As Locative Technologies' Erle notes, Moore's Law took care of that.

Second, the sharing-oriented mindset of the open-source-software community, along with an awareness of the possibilities of the Web, had to penetrate the walls of traditional GIS companies like ESRI. ESRI had long focused its products on industries such as financial services, urban and regional planning, and defense. Its emphasis, understandably, was on building accurate maps to convey critical data, not on tinkering with code or putting fun, interactive maps on the Web *(see "Do Maps Have Morals?" June 2005)*. But over the last several years, conversation within industry standards groups like the Open Geospatial Consortium (of which ESRI is a leading member) and the World Wide Web Consortium at MIT has led to agreement on basic standards for mapping-software APIs—and on additions to the Web's central language, XML, that make it easy to tie Web documents to geographical locations. Embedding the XML tags `<geo:lat>38.888</geo:lat>` and `<geo:long>-77.035</geo:long>` in a Web document, for example, lets mapping or browsing software know that the document is about the Washington Monument.

Third, owners of large, valuable, proprietary databases on the Web needed some time to arrive at the idea that granting outside access to their databases might actually be good for business. Amazon was one of the first companies to put this idea into practice, releasing an API in 2003 that allows programmers to tap into its product database, pull out whatever information they want, and present it on their own websites in any format they choose, as long as any resulting purchases are directed back to Amazon *(see "Amazon: Giving Away the Store," January 2005)*. The basic idea of Web services—that the software and databases powering e-retailing, online photo-sharing, and the like should be built according to standards allowing other parties to tap into them—was still radical even three years ago. Today, however, it's the guiding principle of an increasing number of open-source developers and megacorporations—even Microsoft.

By early 2005, then, the hardware, the standards, and the collaboration models were in place for a burst of innovation in Web mapping applications. All that was needed was a starting gun. The gun fired on February 8—the day Google Maps went online.

Map Mash-Ups

Even on the surface, it's clear that Google Maps goes much further than older interactive map sites. The stunning satellite views, along with the ability to drag the map in any direction without having to wait for the page to refresh, are the most obvious advances. The shaded pop-up balloons pointing to the locations turned up in local searches—Google calls them "info windows"—are also a pleasing touch.

But it's what's under the hood that really excites programmers. Within hours of Google Maps' release, programmers had reverse-engineered it, discovering that most of the interactive features relied on simple miniprograms or "scripts" written in JavaScript, one of the Web's best-known languages for scripting. That meant programmers could write their own JavaScript to manipulate the maps—for example, making their own content, rather than the usual Google search results, appear in the info windows tied to specific map locations.

Almost immediately, programmers started building services atop Google's map infrastructure. Computer graphics expert Paul Rademacher, for example, launched HousingMaps, a site that pulls real-estate listings off the popular classified-ads site craigslist, uses the addresses of the listed homes and apartments in a given neighborhood to figure out their latitudes and longitudes, and lets users view the properties on a Google map. HousingMaps has no affiliation with craigslist or Google; Rademacher built the hybrid site simply by figuring out how to write coded requests that would grab the appropriate data from the two companies' public databases. Fortunately, the companies take a mostly benign view of such mash-ups.

Google is so eager to let outside programmers experiment with its mapping platform, in fact, that it released an official API on June 30, meaning hackers would no longer have to waste time on reverse-engineering. That's led to an even bigger wave of Google Maps creations, from the practical to the disturbing. At ahding.com/cheapgas, you can see gasoline prices from Gasbuddy.com plotted on a Google map, directing you to the lowest-priced pumps in your area. FloridaSexualPredators.com, meanwhile, shows place marks for the homes of every sex offender listed in the Florida Department of Law Enforcement's public database. Clicking on a place mark brings up an info window with the offender's name, address, and mug shot.

Geography as Context

To use the Google Maps API, developers must agree not to use the service for commercial purposes, and so far, even Google has refrained from placing ads on Google Maps pages. But for companies exploring the Internet for the next big business opportunity, the geospatial Web is the equivalent of a virgin continent

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waiting to be planted with billboards. The attraction is especially great for companies in the search business, for one simple reason: interactive maps have the potential to greatly extend the power of contextual advertising—the engine that drives the search industry and accounts for Google's ever rising revenues.

Every time you do a search at Google or read a message in your Gmail inbox, you'll see a different set of ads on the right side of the browser window. This selection isn't random: each ad relates to a keyword appearing somewhere in your search results or in your mail. Users are more likely to notice ads if they relate to products or services they're already looking for, as is demonstrated by measurements of the all-important "click-through" rate for contextual ads, which is higher on average than that for other types of ads, such as banner ads. Because search companies charge advertisers by the click, they have a huge incentive to figure out which ads will be most relevant to a user at any given moment and to make sure he or she sees just those ads.

There's one big drawback to using keywords to tailor ads, however: advertisers lose the opportunity to cater to users' other interests. Say you're searching for tickets to *The Producers* on Broadway. You might also be curious about restaurants near Times Square with early seatings. But today's search technology can't hazard such guesses efficiently—and it may never do so. After all, what search engine could divine that a visitor to Chicago is interested in both Cézanne and architecture?

Maps provide a way out of this dilemma. We may be able to communicate instantly with friends halfway around the globe, but we're still fleshly creatures who must fulfill our basic needs locally. If you're new to a particular area, looking at a map is the most natural way in the world to search out local services. In this case, the "context" for contextual ads is no longer a list of keywords but a location—meaning that the primary measure of an ad's relevance to the user is simply proximity, with no fancy psychographic algorithms required.

The developers in Yahoo's local-services division understood this sooner than Microsoft or Google. In March 2004, they introduced SmartView, a set of buttons alongside a traditional Yahoo map that allows users to highlight points of interest, from spas to sports stadiums. (In an example of custom marketing, the maps can also show special icons for the locations of Carl's Jr. restaurants, Jeep diesel stations, Intel Centrino–certified Wi-Fi hot spots, and other branded services.) "It's cool to see a photo of the Sphinx from a thousand feet up, but we're focused on understanding people's key tasks and helping with those," says Yahoo local-services manager Paul Levine. But Yahoo is also asking outside programmers for help thinking up new ways to deploy Yahoo maps; the company released an API for its mapping service on the same day as Google.

Microsoft, which launched MSN Virtual Earth at the end of July, may appear to be a latecomer to advanced Web mapping. Actually, the company has been in the map business since the early 1990s, offering business-oriented products such as its MapPoint Location Server, which helps companies track shipments or mobile workers, and consumer travel-planning software such as Microsoft Streets and Trips. But Virtual Earth is a different animal, exploiting all the power of the Web-services model to act as something like a "geo-organizer"—a way of managing data intended to complement, and perhaps someday supersede, classic organizational tools such as address books.

The service could become a powerful rival to Yahoo Maps, Google Maps, and even Google Earth. Graphically, it offers satellite views similar to those available from Google Maps. But it also offers some unique features, such as a scratch pad where users can paste in notes about the locations they view. One mouse click lets the user e-mail the scratch pad's contents to friends or publish them to a blog page on MSN Spaces, Microsoft's new blog-hosting service. "You'll be able to take content from Spaces into Virtual Earth and take content from Virtual Earth into Spaces and share it with whomever you want to share it with," says Mark Law, lead product manager for MSN Virtual Earth. That will be a boon for Web users, who will gain a new channel for communicating and sharing digital content. And it will be a boon for Microsoft, since every Web page viewed in the process of sharing represents new real estate for contextual ads.

Annotating the Planet

As the big three vie for Web users' loyalty, they're likely to introduce more ways for people to import their own data and see it displayed on professional-looking maps. Google Earth Plus, an enhanced subscription version of the program, allows users to upload and view data collected by their GPS units, such as "tracklogs," series of virtual bread crumbs showing where the user has been. And other companies are getting into the mix. A program for Nextel GPS camera phones, Trimble Adventure Planner, helps users create online travelogues by uploading photographs and pinning them to the appropriate spots on a Web map.

Siemens, meanwhile, is developing software that will let a GPS-enabled mobile device associate notes with specific coördinates; when someone else with a similarly programmed gadget approaches the coördinates, the note appears on his or her screen. A tourist bureau might "label" a particular spot along San Francisco's Embarcadero as the site of a fatal duel in August 1879. John Udell, a columnist for *InfoWorld*, has coined a phrase for this phenomenon: "annotating the planet."

It's a trend that the main providers of mapping platforms have every incentive to encourage. After all, as the history of the Web itself has shown, interesting content draws more traffic, which drives more click-throughs. "The world is really dense with information," says Schuyler Erle. "Access to ubiquitous networking and location-finding services means that we can take that information and make it accessible in the places we are actually in, when we need it, and that allows us to make much more intelligent decisions on the spot, at that time."

Every page on the Web has a location, in the form of a URL. Now every location can have a Web page—indeed, an infinite stack of them. That may sound like a recipe for information overload. But in fact, it means that navigating both the Web and the real geography around us is about to become a much richer experience, rife with occasions for on-the-spot education and commerce. It means that we will be able to browse the Web—and the virtual earth encompassed within it—simply by walking around. ■

Wade Roush is a TR *senior editor based in San Francisco.*

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KEYNOTE TOPICS

T e Hun re -Dollar Laptop Proje t— Computing for Developing Nations

Can a New T eory of t e Neo ortex Lea to Truly Intelligent Ma ines?

Emerging Te nologies: T e Innovator's View

Tomorrow's Engineering Crisis

Making Seamless Mobility Real Aroun t e Worl

New Growt Opportunities in Computing an Communi ations

Innovation Everyw ere—How t e A eleration of "GNR" (geneti s, nanote nology, roboti s) Will Create a Flat an Equitable W orl

Innovation Everyw ere—W y t e W orl Isn't Flat Enoug

BREAKOUT SESSION TOPICS

So ial Computing

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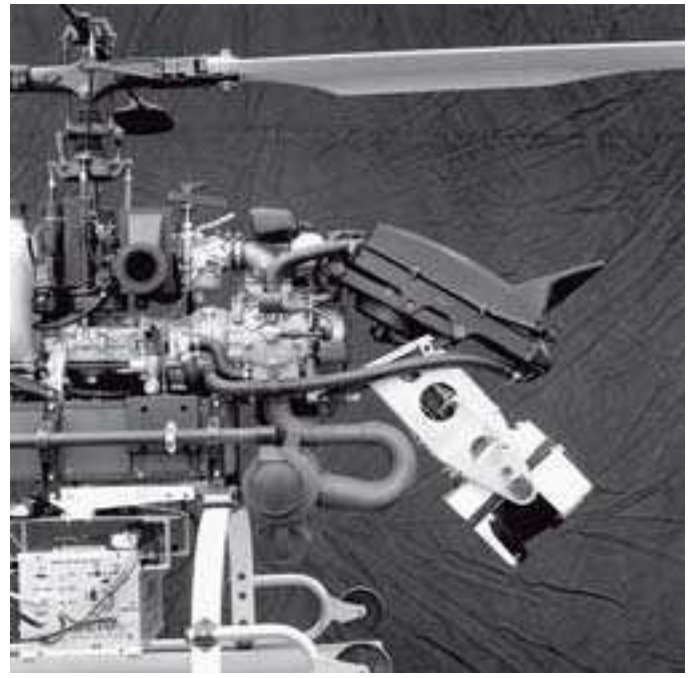
The Robo-Copters

By David Talbot **Photographs by Timothy Archibald**

Posing with *Ursa Maxima 2*—a 12-foot autonomous helicopter rigged with a laser range finder and advanced navigation and control systems—are its builders and handlers: David Shim, head of the Berkeley Aerobot Project (crouching); PhD candidate Hoam Chung (standing right); and staff member Travis Pynn (left).

Autonomous planes are nice, but if you need low-altitude agility and hovering, especially in urban areas, nothing beats a robo-chopper. Several groups are developing them, but the Aerobot Project at the University of California, Berkeley, is a leader in key areas like autonomous obstacle-avoidance and coördination between helicopters. Although the group has made strides in computer vision and other forms of sensing, and in navigation and control software, practical machines are still several years away.



FACING PAGE: Two 12-foot-long autonomous helicopters test competing methods of collision avoidance. One fires light beams from a laser range finder; the other uses Global Positioning System coördinates broadcast over a network. Armed with the resulting information, they navigate away from each other.

THIS PAGE: A five-foot-long chopper designed to carry a video camera sports painted teeth; a human ground controller aims the camera remotely. Right, a view of *Ursa Maxima 2* without its shell. The white box at lower right is its laser range finder.

THIS PAGE: In the Berkeley group's most recent display of technical virtuosity, *Ursa Maxima 2* demonstrates how it can avoid obstacles. The tents are meant to represent city buildings. The helicopter actively senses them with its laser range finder and, without any previous knowledge of the environment, finds openings and develops a navigation plan to fly between the canopies. **FACING PAGE:** Chung sits in the ground-control station, a trailer at Berkeley's test field in Richmond, CA, and monitors helicopters' real-time status. The screen in the background can display images captured by a helicopter or operating parameters like velocity, attitude, and direction of travel.

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Can an inventive society get bolder as it grows older? That question affects people of all ages—especially those living in the United States, Europe, and Japan, which are expected to have fewer workers supporting more retirees.

According to *Science and Engineering Indicators: 2002*, issued by the National Science Board (NSB), an independent legislative and executive advisory body established by the U.S. Congress in 1950, America's science and engineering workforce will continue to grow in coming decades, but its average age is likely to rise. Will scientific workers in their 50s and 60s continue to make valuable contributions?

The report avoided asking whether aging impairs creativity. If it does, then the growth of our productivity and improvement of our standard of living might be in trouble. There is already a shortage of young Americans in research; in 2003 the NSB expressed concern over the United States' dependence on foreign PhDs.

Scientists, often older ones, have for years questioned how long they can stay productive. G. H. Hardy set the tone in his 1940 classic, *A Mathematician's Apology*. "Like any other mathematician who has passed sixty," Hardy confessed, "I have no longer the freshness of mind, the energy, or the patience to carry on effectively with my proper job." He continued that "mathematics...is a young man's game."

The age lore of other sciences can be similarly misleading. The Nobel laureate physicist Paul Dirac has suggested, tongue in cheek, that a physicist over 30 was as good as dead, and the physicist-historian Abraham Pais wrote of Einstein after 1925 (when Einstein was 46) that, as far as his work went, he might as well have gone fishing. And yet the sociologist Harriet Zuckerman, in her landmark 1977 book, *Scientific Elite*, observed that U.S. Nobelists received their prizes for work done when they were, on average, nearly 39. Sir Nevill Mott won a Nobel in physics for his postretirement research.

Thomas Edison, the inventor of the disc phonograph, pictured above at age 77.

Great biologists seem especially hardy. The German naturalist Alexander von Humboldt successfully surveyed harsh, remote areas of the Russian Empire for goldfields after turning 60, and began publishing the 19th century's greatest work of synthesis, *Cosmos*, at age 76; he had completed 2,000 pages by his death at 89, in 1859. More recently, Harvard University's Ernst Mayr was still writing papers at 100.

Why, then, do certain researchers stagnate while others flourish? Some might be internalizing what Zuckerman called the "mythology" of aging in science. But another factor is that any education has built-in limits. Even Einstein may have been bumping against them. Scientists over 40 face a choice: continue using the endowments that have served them well but are challenged by a new generation, or turn to new subjects.

Thus Humboldt—who had earned his fame in the tropics—turned to the bleak North. In his early 50s, Wilhelm Ostwald resigned his chair of physical chemistry at the University of Leipzig to pursue philosophy, color theory, and the promotion of scientific knowledge. He is honored not only for the chemical discoveries that led to his Nobel Prize in 1909 but for his work on an early version of the hypertext concept.

For engineering and invention, the implications of an aging brain trust are quite apparent. There, too, young people are responsible for many basic innovations. But that doesn't mean they will stagnate as they age. Thomas Edison was in his late 60s when he developed the disc phonograph. Shumpei Yamazaki of Japan, the inventor of flash memory, has at 62 just displaced Edison in the Guinness book of records, after pointing out that his 3,245 patents exceeded Edison's 2,332. Othmar Ammann designed New York's Verrazano-Narrows Bridge in his late 70s; the Swiss engineer Christian Menn completed the revolutionary cable-stayed Zakim Bunker Hill Bridge in Boston at 75.

What is the secret of such men and women? Partly, it is that they do not expect the flashes of mathematical insight that may indeed be the prerogative of the plastic youthful brain, but instead forge new syntheses aided by experience.

For some, this drawing on experience can become an ever renewing source of inspiration. Germany's most prolific patenter, Artur Fischer, made a breakthrough as a young man in 1948 with Germany's, and perhaps the world's, first electrical system for triggering a photographic flashgun automatically when the shutter is released. He then applied his research on plastic parts in projection screens to the development of a bestselling nylon wall anchor for the building trades, millions of which are still made daily by the firm he founded. The principle of this plastic-sheathed bolt in turn became a key element in his line of model-building kits, Fischertechnik, which is used by industrial prototypers as well as schoolchildren. At 85 he has developed a system for making biodegradable toys from potato starch.

As Fischer has aged, the markets for his ideas have grown younger. To attract more kids to invention, it might help to show them that talent has no expiration date. ■

Reviews

Our reviews use any artifact—a book, a product, a government report, a movie, a research paper—as the occasion for a contemplative essay on some technological controversy.

The Get-Ready Men

The cheap oil will end one day. What about civilization?

BY BRYANT URSTADT

We will run out of cheap oil, either now or later. The most pessimistic disciples of the late geologist M. King Hubbert believe that production will peak somewhere between 2000 and 2010. Others suggest that production may top out a few decades after that. What will happen next is unknown, but an increasing number of the peak-oil handicappers share the dark beliefs of James Howard Kunstler, who predicts that alternative energy sources will never meet our needs and that we are in for a "rough ride through uncharted territory," which will take us "off the edge of a cliff" and thence into "an abyss of economic and political disorder on a scale that no one has ever seen before." The sprawl of metaphors is characteristic of Kunstler, who in *The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century* adds a relentless, scary, and entertaining voice to the rising alarm about life after the cheap oil is gone.

Prophets have been warning Americans of the terrible things in store for decades, but Kunstler joins a fresh corps whose numbers seem to have been increasing as quickly as the price of gas. The past two years have seen books with titles like Paul Roberts's *The End of Oil*, Richard Heinberg's *The Party's Over*, Tom Mast's *Over a Barrel*, and David Goodstein's *Out of Gas* and a film called *The End of Suburbia* by Gregory Greene, to name a few, and to leave out their long and unsettling subtitles, most of which approximate Roberts's choice, which is *On the Edge of a Perilous New World*. These authors may someday join the ranks of the dated alarmists—Jeremy Rifkin, among countless others, issued similar warnings in *Entropy* in 1980—but then again, they may be right. One may demonstrate that the alarm rings too often and too soon, but that does not mean that danger will never come.

Kunstler's predictions may seem excessively dire to many, but a significant number of people are paying attention and getting ready. His book has been hovering in the top 1,000 on Amazon.com for months, and the topic of peak oil has gained traction beyond the encouraging environment of the Internet. In the past 18 months, 82 groups with about 2,000 registered members in cities around the world have been organized through Meetup.com to discuss the issue. At a recent meeting of the 100-member New York forum, participants were quoting Kunstler repeatedly—during, for instance, a discussion of where to move after the crash.

Our particular problem, Kunstler and his colleagues continually remind us, is that we have built a world based on the ready availability of cheap energy. The apocalyptic catch, though, in their view, is that oil was a "one-shot deal," and there will never be another power source as easy to extract, as portable, and as powerful. When the oil dries up, writes Kunstler, "all bets are off against civilization's future."

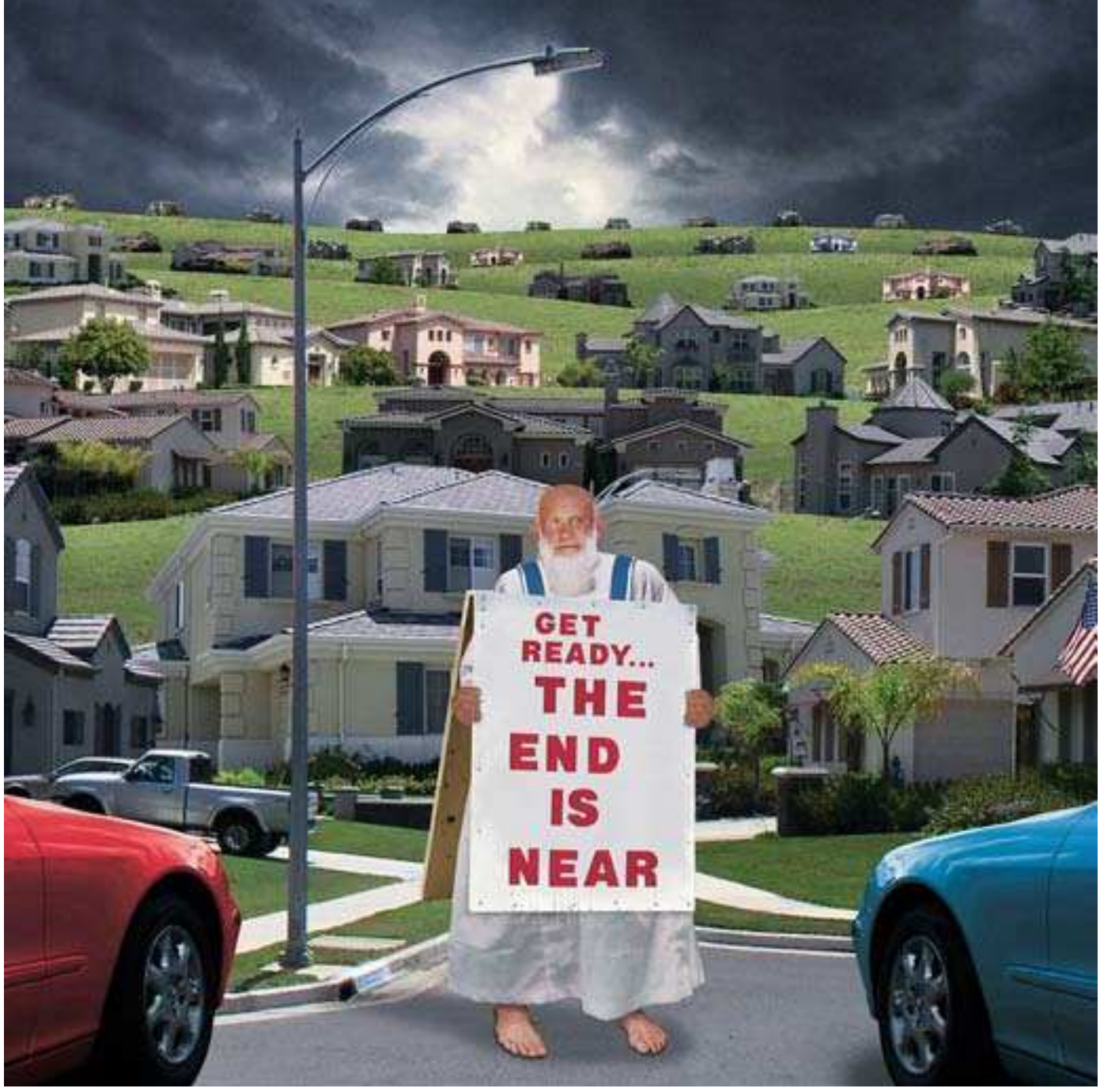
The internal logic of the argument is persuasive, and one reads all the books with white knuckles. Oil has seeped into every nook of our existence. At the most basic level, we need oil to grow our food, particularly as we have moved to large-scale, fertilizer-dependent agriculture, and we need oil to get that food to our communities.

Scary Stuff

The Long Emergency: Surviving the Converging Catastrophes of the Twenty-First Century
By James Howard Kunstler
Atlantic Monthly Press, 2005, $23.00

Things might be simpler if our appetites were limited to food. But the range of our activities has broadened considerably, and oil supports almost all of them. We need oil to make most of the things we use every day—from plastic to the roads we drive on—and, more importantly, to get them from the hands of cheap laborers and into our big box stores, to which we drive in large cars, of course. Oil now satisfies about 40 percent of our energy needs, and about two-thirds of it we burn in motors, going places and moving things or sitting in traffic.

Kunstler does not believe the United States will survive as we know it but will instead break down into autonomous, isolated regions. The fun is certainly over in the desert United States. According to Kunstler, cities like Las Vegas—dependent on cheap air conditioning, air travel, and good highways—will wither into dust. Around the country, a trip to town will become a day's ex-



DENNIS IRWIN

cursion, a trip to the nearest large city a journey of several days, and a trip across the country nearly unthinkable. The suburbs—which Kunstler calls "the greatest misallocation of resources in the history of the world," and for which he seems to reserve a special contempt—will become particularly miserable places, devolving into wastelands of abandoned McMansions, empty Wal-Marts, and disintegrating asphalt. We will not be able to heat our 5,000-square-foot houses, if we can get to them, and we will not be able to fill the box stores with Chinese goods, or to resurface the roads, which we won't be using much in any case.

As for the rest of the world, Europe may fare slightly better, having to some extent preserved the small, agriculture-friendly, locally focused communities that Kunstler believes will dominate the post-oil world. But overall, the strife will be biblical: "Australia and New Zealand may fall victim to desperate Chinese adventuring.... The coastlines of all nations may become prey to a new species of stateless freebooting raiders.... The Pacific coast of North America will be especially vulnerable to raids emanating from the disintegrating nations of Asia." Poor nations will never develop but will seem unexceptional among "the hardship and chaos that will become common elsewhere."

These predictions of collapse all presuppose that we cannot be saved by alternative energy sources. Kunstler dismisses alternative energy as a "mirage" and belief in it as "a holdover from the techno-miracle cavalcade of the twentieth century." He does his best to demolish any hope for natural gas, solar and wind power, coal, hydroelectric power, biomass, or nuclear power. Though he succeeds in provoking thought, he does not quite convince the optimist that we are doomed.

He discounts natural gas as a long-term solution, and with good reason, for it suffers from most of the same reserve problems as oil, compounded by problems of getting it from the field to the user. But he does undervalue it as a "bridge" supply, a form of energy that might be used to help us make the transition to the

next source. And the scarcity of bridge power is crucial to many of his assumptions about whether we will have enough energy to build the next generation of sources.

He is doubtful about solar power, too, pointing out that the infrastructure to obtain it, as it exists today, relies on the petroleum economy in a number of ways, not least for the plastic that goes into batteries and photovoltaic-cell arrays. Ditto for wind turbines, which require a fair amount of machinery, currently petroleum based, for their installation. Objections like this—where Kunstler asks, could we survive on the output of this source *alone*?—are raised frequently and are certainly the weakest point in his argument. Meanwhile, many knowledgeable optimists have yet to dismiss the potential of either solar or wind: companies like GE and Boeing have been making major investments in solar energies for years, even renewing interest in and work on once marginalized technologies like the Stirling engine, which could run on concentrated solar heat. Wind, too, has turned some corporate heads: Goldman Sachs, for instance, recently acquired Houston-based Zilkha Renewable Energy, which builds wind farms. Still, as Kunstler points out, solar and wind are very inefficient compared with burning petroleum products and possibly unsuited to running a public transportation network, much less the car-based system we have now.

Coal is already producing about half of our electricity, and though most agree that it is in good supply, Kunstler is dubious about the numbers. The environmental cost of burning it is also, as Kunstler notes, extreme: beyond coal's contribution to global warming and other, more local forms of air pollution, it is hard to dismiss the large-scale leveling of landscapes. As for synthesizing oil from coal or, for that matter, extracting it from shale and tar sands, it can happen; but the high cost and the limited return on the energy invested are not likely to allow anything like the enormous economic expansion of the last century. Nor, given the likely outcome of continued global warming, should we be overly encouraging of coal conversion. But neither does this mean that the slow-moving work on clean coal will never bear fruit.

Kunstler is skeptical, too, about hydroelectric power—which is much cleaner—on the grounds that we will not be able to maintain the infrastructure for building dams without our cheap oil. And though hydroelectric power meets about 10 percent of our electricity needs today, Kunstler believes that room for growth is limited, as many of the best dam sites are already taken. Again, Kunstler is assuming the worst case. It is quite possible, for instance, that we will build and maintain dams with equipment that runs on expensive oil, if we can, or with some kind of coal-powered steam shovel, if we must.

Kunstler's argument against biomass is that making it in useful quantities requires massive industrial farming powered by... cheap oil. There is some truth here. But biomass advocates are more sanguine, arguing that fuel could be produced from naturally fecund prairie grasses, among other things. And as former assistant secretary of energy Dan Reicher has pointed out, biomass production inherently reduces the concentration of greenhouse gases in the atmosphere: plant life, after all, consumes carbon dioxide. Kunstler is slightly bullish on the usefulness of one form of biomass, wood—with a chilling caveat. He expects it will heat our homes nicely in the absence of cheap oil and that, consequently, the "future deforestation of North America (and Europe) could be as rapid and dramatic as the extermination of the American bison in the decades after the Civil War."

That leaves nuclear, as Kunstler and so many others have been noticing lately (see Stewart Brand's "Environmental Heresies" in our May 2005 issue). Still, Kunstler accepts nuclear power's ascension reluctantly, unsure as in other cases that we will be able to maintain a nuclear infrastructure using nuclear power alone and doubtful that we will be able to convert that power into a transportation system anywhere near as massive as the one we now have. But even if the large four-wheel-drive truck may someday be an obsolete method of picking up milk, that does not mean we will be back on horses: even the mass-transit-averse U.S. has had reasonable success with electric trains.

Overall, Kunstler's tapestry of destruction assumes a race of much more limited flexibility and creativity than history shows humanity to be. He *could* be right, of course; and given our behavior in the past hundred years, there may be a perverse satisfaction in agreeing with his assessments of our capabilities and our future. But more likely we will muddle through as we almost always have, flourishing here, waning there, and surprising ourselves, perhaps undeservedly. It seems more realistic to assume that as the price of oil continues to rise, rather than focusing myopically on oil technology, we will try a number of other options at once, looking with our usual expediency for an easy solution that does not kill us, at least for the moment. We may end up with inefficient solar panels on our roofs, kicking electricity back in to the grid in a trickle; a somewhat more efficient biomass plant at the end of the block; and a transportation system running on fuel cells charged with electricity from nuclear plants. Las Vegas may even get off the hook, harnessing the geothermal resources of the West. And none of this takes into consideration improvements in how efficiently we consume energy.

Kunstler's tapestry of destruction assumes a race of much more limited flexibility and creativity than history shows humanity to be.

Most of all, despite its urgency, Kunstler's book reminds us how modern man is scared by his own inventions. We've been expecting to die by our own hand at least since Hiroshima, and even younger readers may share relief at having somehow escaped the ravages of a nuclear winter, a homemade dirty bomb, and a world-destroying clerical error in January 2000.

In *My Life and Hard Times*, James Thurber describes a citizen in his childhood town of Columbus, OH: the Get-Ready Man. The Get-Ready Man drove a car with a door in the back and liked to shout at people as he drove, using a megaphone. His warning was always the same: "Get Ready! Get read-y...! The worlld is coming to an End!" Kunstler and the others may join the Get-Ready Man in the annals of doomsday prophets, and the Peak Oil Apocalypse may get filed along with Y2K under "false alarms and other diversions." Even now, it may be dismissed by some with laughter. But it ought to be nervous laughter. ■

Bryant Urstadt has written for Harper's, Rolling Stone, *and the* New Yorker. *His most recent article for* Technology Review *was "Wild Profits," in April.*

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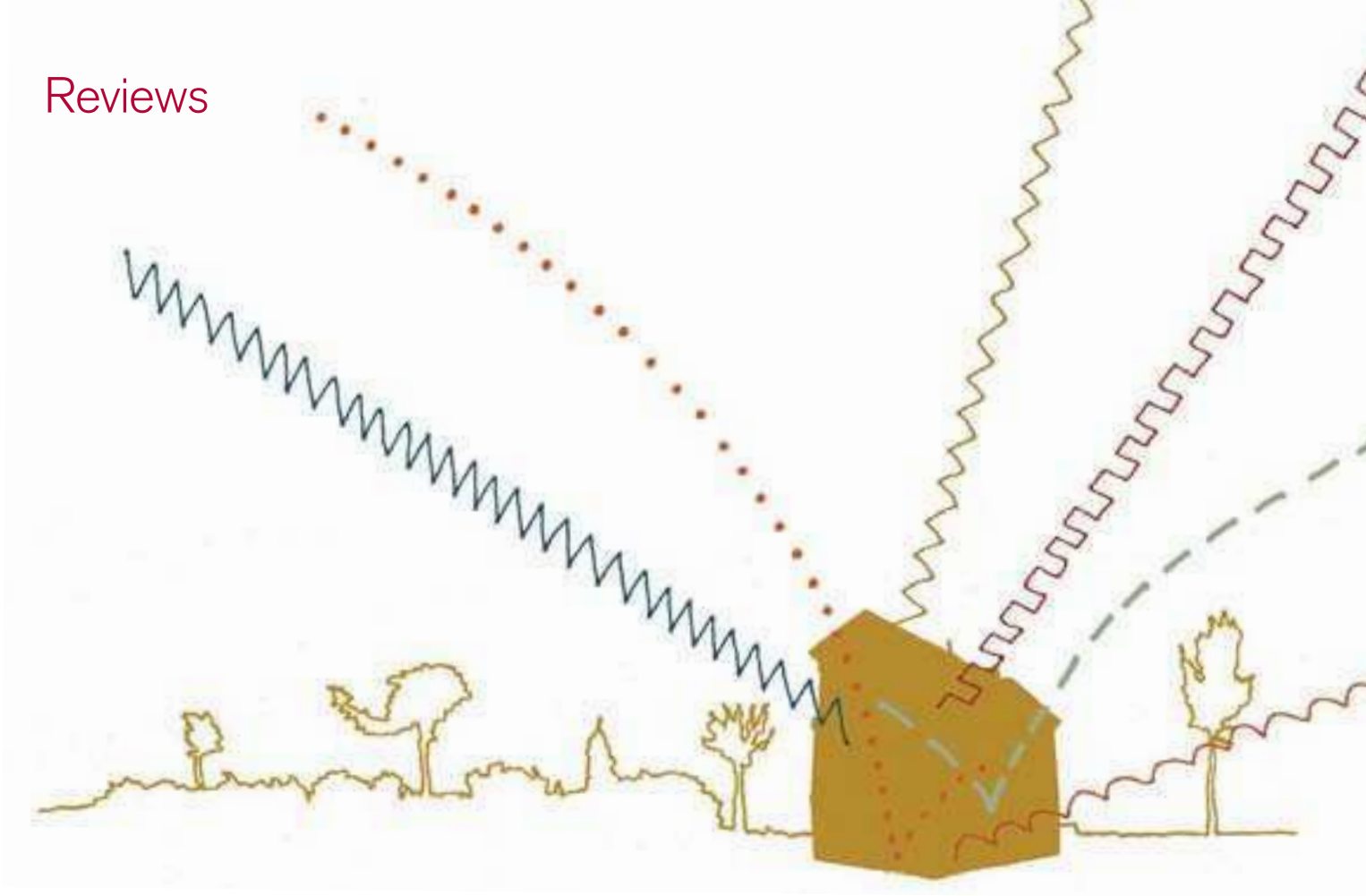


Hearing Multiple Signals

MIMO, the new wireless technology, promises faster and more powerful Wi-Fi. But just how well does it work?

BY MICHAEL FITZGERALD

Anyone who uses wireless anything—a Wi-Fi network at a hotel, cellular phones, BlackBerries—knows some of the problems with the technology: Wireless networks transmit data much more slowly than most wired ones, they don't always work, and they have a maddening tendency to disconnect without warning. There's a constant worry of being out of range or having a bad connection. Still, each new generation of wireless gadgets gets better, generally cheaper, and seemingly more popular. Now an emerging wireless networking technology called MIMO promises real breakthroughs in speed, accessibility, and reliability. That has implications for today's corporate networks, home Wi-Fi networks, and cellular networks.

MIMO stands for "multiple input, multiple output." Wi-Fi routers based on the technology use a series of radios in conjunction with several "smart" antennas to send and receive signals simultaneously. Handling multiple signals makes possible much stronger, more reliable, and faster transmissions—in theory.

Consumers will see MIMO in a new class of wireless networking products categorized as "pre-n," after the nomenclature of the Institute of Electrical and Electronics Engineers' 802.11 wireless Ethernet standards committee. The IEEE wireless standards with the broadest impact have been, in the order in which they reached market, 802.11b, 802.11a, and 802.11g. There is not yet an 802.11n, but the consumer market for pre-n products is already flourishing. One of the leading manufacturers, Airgo Networks, a Palo Alto, CA, startup, has already sold more than four million MIMO chipsets, which appear in wireless networking routers and adaptors from LinkSys, Belkin, and other vendors.

Wireless Wonders

Belkin Wireless Pre-N Router ($150) and Wireless Pre-N Notebook Network Card ($100)

Indeed, while MIMO has not yet become a Wi-Fi standard, routers and PC cards based on it are easy to find, both online and in stores. Samsung has even put MIMO on the motherboards of two of its notebook computer models selling in Asia and Europe (most U.S. electronics companies are expected to wait until the IEEE approves its standard before integrating MIMO into their systems). Meanwhile, Orthogon Systems, a British startup, has begun offering networking equipment aimed at long-range networks that uses a method similar to MIMO.

RODERICK MILLS

To see how well MIMO actually works, I bought a Belkin router that uses the Airgo chipset. The router is equipped with three radios and three antennas, which are intended to increase its range, reliability, and speed. In fact, Belkin claims an 800 percent improvement in coverage area over the best of current Wi-Fi routers and a 600 percent improvement in speed.

I had not previously set up a wireless router. And since my technical skills mostly involve breaking things in ways their makers had not imagined, I expected a challenge. I popped the installation CD into my notebook's drive and followed the instructions. When it came time, I plugged in the router, which boasted four Ethernet ports to connect to PCs, one port for the modem, and a plug for a power cord on one end and three nubby antennas sticking out of the other. Windows XP Home Edition, which I use, protested that I was installing an unknown device that could destabilize my system. Nevertheless, I pressed on.

To get Internet access, I ran a cable from my DSL modem to the router, which sits in my basement office, and then another cable from the router to my notebook computer. That worked fine. But when I installed the MIMO notebook card and pulled the cable, I lost my connection. It took a bit of poking around in the software that comes with the system to realize I needed to tell it to activate. (Okay, so the truth is, I was on the phone interviewing someone for this story and complained about the lost connection. He asked me whether the radio was on. One right-click of the mouse later, it was.)

Including the basement, our house is about 3,000 square feet, but even in the farthest point from the MIMO router, I have no connectivity problems and no drop-off in download speeds. In fact, Belkin claims good connectivity over 250,000 square feet (the fastest current version of Wi-Fi, 802.11g, generally covers less than one-fifth that), so I could probably read e-mail while mowing my lawn, if I felt like it. And the MIMO notebook card works fine in the local coffee shop, using the existing Wi-Fi standard.

In short, MIMO looks to be a good thing for people and businesses whose connectivity is spotty and unreliable or who experience slow data transmission for PCs at the extreme ends of their current Wi-Fi networks' reach. That's nice, but the importance of MIMO goes far beyond improving the performance of Wi-Fi. It is, in fact, "the most significant radio technology ever," claims wireless consultant Craig Mathias, principal at the Farpoint Group in Ashland, MA. The reason for such excitement is that MIMO appears to be an excellent answer to a wireless problem that's existed since Marconi.

"In wireless communication, the biggest problem has always been multipath interference—signals taking different paths and canceling each other out or blurring the signal," explains Ira Brodsky, president of Datacomm Research in St. Louis. The result of this interference is familiar to anyone who's ever had trouble tuning in a station over a car radio: signal drops—the very thing wireless networks must be engineered to prevent.

MIMO is designed to turn this inherent problem with wireless into an advantage. In a sense, MIMO is to wireless what multiprocessing is to computing—a way to move data faster by sending it through multiple channels. Each of the radios on the MIMO chipset pulls in a signal, and all the signals are then run through digital signal-processing algorithms and re-formed into a single transmission. This use of redundant multiple signals allows MIMO to increase the reliability and range of transmissions. Indeed, the strategy is widely applicable, and over the next several years, MIMO technology may make its way into cellular networks and products that might benefit from wireless transmission, like camcorders and televisions.

The exact origins of today's MIMO technology are disputed, which seems fitting, since there is no agreement on its exact definition, either. There are various versions of the technology with such esoteric names as "spatial diversity multiplexing," "beamforming," "antenna diversity," and "channel beaming." What is clear is that Airgo, headed by CEO Greg Raleigh, who as a graduate student at Stanford University in the 1990s helped pioneer MIMO, is the first company to come up with a version cheap enough to make it onto the consumer market.

Adding to the confusion around MIMO is that it is to be the basis for the IEEE's 802.11n standard, which is not yet a standard and is not expected to become one until at least 2007.

In a sense, MIMO is to wireless what multiprocessing is to computing—a way to move data much faster by efficiently sending it through multiple channels.

The bottom line for consumers? People who buy MIMO products before 2007 will eventually have to buy new products to get the full speed advantages of the technique when the standard has finally been finished, predicts Robert W. Heath, an assistant professor in electrical and computer engineering at the University of Texas at Austin. Still, if MIMO keeps improving, it might be well worth it.

A wireless network's performance isn't based on just one factor, of course: my router can't download data from the Web any faster than my DSL connection allows. Network speed is measured in megabits, or millions of bits, per second, and my DSL on a good day hits two megabits a second. My router's claimed top speed is 108 megabits a second. So though I knew the MIMO router wouldn't let my laptop access the Internet any faster, I did hope that I could use it to enhance my house's feeble wireless capabilities. Having noticed new televisions with built-in Wi-Fi, I imagined using MIMO to zip downloads from digital video cameras to the TV, or even to take stuff from the digital video recorder and zap it to one of our other TVs. In fact, I was letting my imagination run amok, warns Mathias. MIMO isn't yet fast enough to handle large amounts of video.

And MIMO won't be a universal solution. In some kinds of wireless networks, such as sensor or radio frequency ID networks, single radios will always be adequate—and cheaper. But for anything that involves data or voice, MIMO is likely to be adopted. For those uses, speed of data transfer is important. And MIMO looks like the technology that will finally let wireless networks start to close the gap between their speed and reliability and those of wired networks. ■

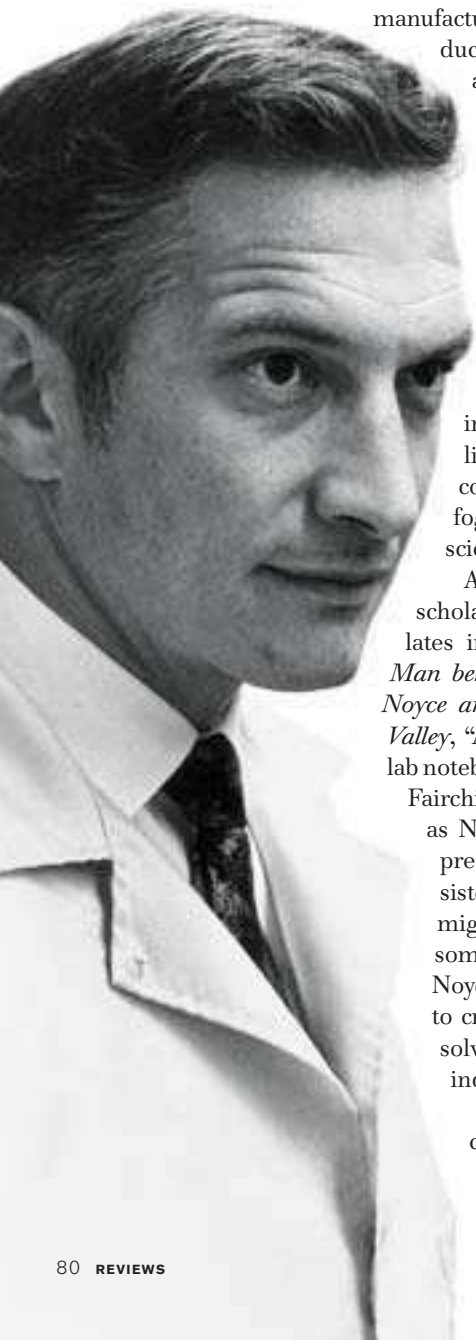
Michael Fitzgerald is a freelance writer who lives outside Boston. A frequent contributor to Technology Review, *he has also written for the* Economist *and the New York* Times.

The Integrator

Robert Noyce dreamed up the microchip in a 1959 notebook entry.

BY ROGER LOWENSTEIN

THE REVELATORY MOMENT of the electronics age arguably came in January 1959, when Robert Noyce, an engineer and a founder of Fairchild Semiconductor, scrawled in his notebook the words "Methods of Isolating Multiple Devices." Under that obscure heading, Noyce went on to write, "In many applications now it would be desirable to make multiple devices on a single piece of silicon in order to be able to make interconnections between devices as part of the manufacturing process, and thus reduce size, weight, etc., as well as cost per active element."



Although the word for it did not yet exist, Noyce was describing the microchip. A former protégé of William Shockley, the coinventor of the transistor, Noyce understood the transformative potential of new technology as well as anyone alive. His halting follow-up on his initial idea therefore casts light not just on the history of computers but on the often befogged pathways that lead to scientific advancement.

As Leslie Berlin, a visiting scholar at Stanford University, relates in her new biography, *The Man behind the Microchip: Robert Noyce and the Invention of Silicon Valley*, "After noting his ideas in his lab notebook, Noyce did...nothing."

Fairchild was a new company, and, as Noyce later recalled, he was preoccupied with selling transistors, not with inventions "that might make you some money somewhere down the road." Noyce did not "invent" the chip to create something new but to solve an existing problem in an industrial process.

The problem was that circuits consisted of numerous discrete components (transistors, resistors, and so forth) requiring thousands of interconnections. Electronics users configured their own circuits by attaching these components to each other one at a time, "a process fraught," Berlin tells us, "with errors and failures." As the number of interconnections rose, so did the odds of system failure. By the late 1950s, a score of companies were looking for a solution.

Two months after Noyce's notebook entry, Texas Instruments announced that one of its engineers, Jack Kilby, had invented a crude integrated circuit. This may have been the spark that inspired Noyce to return to his notebook. In July, five months after Kilby, Noyce filed a patent on an integrated circuit. Though Kilby was first, he merely placed all the components on a single slab of germanium and wired them together the standard way—by hand. Noyce's design was easier to mass-produce. His integrated circuit connected components in a single circuit on a chip of silicon that was small enough, as Berlin writes, to be "carried off by an ant."

Chip Maker

The Man behind the Microchip: Robert Noyce and the Invention of Silicon Valley
By Leslie Berlin
Oxford University Press, 2005, $30.00

Berlin's rigorously factual account portrays the scientific process in all its grittiness. Not only were the events that led to the Fairchild integrated circuit "murky" (Noyce was inspired by the work of one of his colleagues, Jean Hoerni), but after the fact, the engineers failed to realize what they had wrought. Some executives within Fairchild were opposed to investing in the commercial development of integrated circuits on the grounds that they were prohibitively expensive and threatened transistor sales.

But Fairchild didn't quite give up. In 1961, it did launch a primitive integrated circuit dubbed the Micrologic, though the $100 price tag limited demand. Finally, in 1964, Noyce made a bold decision: to cut the price of the circuit below what it was costing Fairchild's customers to buy and then solder the individual components themselves. Once the chip became economical to purchase, sales took off. Fellow Fairchild founder Gordon Moore later said the decision to cut prices was as important as the invention itself. It established a pattern for Silicon Valley that still endures. As Moore put it, "Whenever there's a problem, you lower the price." By 1965, Noyce *could* see the future. He told a group of financial analysts to get ready for portable telephones, personal paging systems, and palm-sized televisions.

In 1968, Noyce and Moore bolted from Fairchild and founded Intel. There, Noyce rather sadly became a front man and eventually a figurehead. Berlin does not spare us the depiction of Noyce's shortcomings, including the details of his troubled first marriage. After Intel, he became a lobbyist for the semiconductor industry—not the finale one envisions for a legend, but in keeping with Noyce's modest self-appraisal.

He was often asked when he would win the Nobel Prize. "They don't give Nobel Prizes for engineering," he would say with a smile. Noyce died in 1990. Had he lived, he undoubtedly would have shared the stage with Kilby, who in 2000 did indeed win a Nobel in physics for ushering in the age of computers. ■

Roger Lowenstein is the author of When Genius Failed *and* Origins of the Crash.

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From the Lab

A good place to look for the important technologies of tomorrow is in the scientific discoveries of today. Based on recommendations from academia and industry, *Technology Review* has chosen these peer-reviewed papers as ones that may one day inspire the development of those technologies.

Researchers in India watch a recorded remote teaching session, one possible application for the long-range Wi-Fi technology they're developing.

COURTESY OF BHASKARAN RAMAN

INFORMATION TECHNOLOGY

Long-Distance Wi-Fi

Protocol extends the range of wireless networks

RESULTS: Researchers in India have developed a communications protocol to increase the coverage area of Wi-Fi mesh networks. In a conventional Wi-Fi network—like the ones that are now common at many urban cafés and airports—a base station with a wired connection to the Internet exchanges radio signals with users' portable devices. In a Wi-Fi mesh network, by contrast, several nodes can exchange radio signals with each other as well as with users. Such a network can provide Wi-Fi coverage for a given geographical area at a lower cost than a series of conventional Wi-Fi networks, because not all of its nodes must be wired to the Internet. The new protocol enables off-the-shelf Wi-Fi radios to form mesh networks with distances of up to 40 kilometers between their nodes—compared with one kilometer or less for existing Wi-Fi mesh networks—while maintaining or even increasing data transfer speeds.

In a simulation of a mesh network with nodes at least seven kilometers apart, the researchers achieved data transmission speeds 20 times as high as those possible with Wi-Fi's existing protocol.

WHY IT MATTERS: Wi-Fi networks are cheap and easy to set up, but their transmitters have a range of only about 100 meters. Meshed Wi-Fi networks can cover large urban and rural areas, but they don't solve the problem of Wi-Fi's inherently short range. Current Wi-Fi mesh networks typically require several nodes per square kilometer. Having fewer nodes spaced farther apart can result in lower data speeds and reliability. Because the new communications protocol, developed by Bhaskaran Raman and Kameswari Chebrolu of the Indian Institute of Technology in Kanpur, increases the range of Wi-Fi while maintaining high data speeds or even increasing them, it may reduce the number of nodes needed and hence the cost of blanketing a large area with wireless Internet access, all without sacrificing performance.

Other technologies, including more-powerful antennas, have been developed to increase the range of Wi-Fi transmitters, but they work for only two nodes at a time; the new protocol enables multiple nodes to communicate with each other over long distances, while reducing interference and thus maximizing data speeds.

METHODS: Every wireless network must have a communications protocol called a medium access control (MAC), which coördinates which radios can send signals when, so that they all transmit in an orderly fashion. In a mesh network, a node consists of multiple radios, each transmitting independently on a separate link to another node. The current MAC for Wi-Fi mesh networks allows some radios in a node to transmit signals at the same time that other radios are receiving signals, leading to interference that can slow the rate of data transfer and cause other problems. The researchers' MAC makes the radios in the same node either transmit only or receive only at any given time, avoiding interference and increasing data transmission speeds.

NEXT STEP: The researchers plan to test their protocol in an outdoor deployment of a Wi-Fi mesh network covering 32 rural Indian villages. One intended application is two-way video to enable patients to "visit" doctors remotely. **Corie Lok**

Source: Raman, B., and K. Chebrolu. 2005. Design and evaluation of a new MAC protocol for long-distance 802.11 mesh networks. Presented at the Eleventh Annual International Conference on Mobile Computing and Networking. August 28–September 2. Cologne, Germany.

Gesture Recognizer

Computer interface understands gestures and speech

RESULTS: Researchers from MIT have developed a computer interface that enables a user to manipulate virtual shapes projected onto a screen using gestures, such as pointing, and spoken commands, such as "make a red cube in the middle of the screen." Standing in front of cameras mounted above the screen, a user can create a virtual cube, rotate it, and change its color and size. In one experiment, the researchers found that their gesture recognition system had an error rate of 6 to 17 percent with some gestures, but a zero error rate when the gesture was coupled with a corresponding spoken command.

WHY IT MATTERS: Using gestures and speech to control computers can be easier and more natural than using a keyboard and mouse. Commercial gesture interfaces, such as those that TV meteorologists use to interact with digital maps during newscasts, respond to hand or head movements in two dimensions and require the user to be a fixed distance from the camera. Other systems recognize full-body movements, but typically require users to wear markers or special garments, which can be cumbersome. This system, designed by David Demirdjian and colleagues, recognizes head, torso, and arm movements in three dimensions. Users don't need to wear markers, and the system responds in real time. By combining gesture and voice inputs, the system more accurately follows different commands.

METHODS: The software runs on a PC connected to three cameras and a microphone array. The researchers asked 10 subjects to perform 50 gestures in front of the cameras. Half of this data was used to "train" the software to recognize specific gestures. The software works by first estimating the user's body position based on the camera images and then putting together sequences of poses to identify gestures. The researchers incorporated an existing speech recognition system into their setup. They used the other half of the gesture data from the performing subjects to test the overall accuracy of their system.

NEXT STEP: The researchers would like to improve their software so that it recognizes more-natural gestures and handles conversational interactions. They would also like their system to be able to recognize gestures from multiple users at the same time. **Corie Lok**

Source: Demirdjian, D., T. Ko, and T. Darrell. 2005. Untethered gesture acquisition and recognition for virtual world manipulation. *Virtual Reality*. In press.

BIOTECHNOLOGY

Fatty-Acid Factories

Engineered seeds produce healthful oils

RESULTS: Canadian researchers have engineered mustard seeds to make very-long-chain polyunsaturated fatty acids such as omega-3 fatty acids that are known to reduce the risk of death from heart attacks and strokes. By transplanting genes from six sources, including marine fungi and marigolds, into the mustard plant, the researchers built new metabolic pathways that enabled the plants' seeds to convert two fatty acids they ordinarily make into two omega-3 fatty acids they don't normally make: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The seeds produced a commercially viable amount of EPA, which topped out at 15 percent of the total fatty acids in the seed oil, and a detectable but not commercially viable amount of DHA, at 1.5 percent.

COURTESY OF XIAO QIU

Seeds from the India mustard plant were engineered by researchers to make healthful oils.

WHY IT MATTERS: Omega-3 acids are found primarily in fish oils, and food manufacturers have recently been extracting them and adding them to eggs, milk, juice, butter, breads, and other foods. But while these acids are good for people's health, their source, fish oil, can contain high levels of toxic chemicals such as mercury. By turning mustard seeds—chosen because they normally produce large amounts of oils and can easily incorporate new genes—into fatty-acid factories, the researchers hope to produce a safe source of omega-3 acids not limited by the supply of fish. Previously engineered plants produced low levels of EPA and no DHA. Here, an engineered mustard seed produced DHA for the first time and high enough levels of EPA to make it a potential commercial source.

METHODS: Led by Xiao Qiu of Bioriginal Food and Science in Saskatoon, Saskatchewan, the researchers introduced three to nine genes from plants and microörganisms into the cells of India mustard seedlings, then analyzed the oils in the seeds those plants produced. The new genes produced enzymes that in a series of steps transformed the two normally present fatty acids into the omega-3 fatty acids. By adding genes successively in a series of experiments, the researchers could see how each gene changed fatty-acid production, which allowed them to understand in detail the metabolic pathways involved and to try different genes that would produce higher yields of the target fatty acids.

NEXT STEP: The researchers are attempting to increase the seeds' production of DHA by adding more genes to the omega-3 fatty-acid pathways. **Kevin Bullis**

Source: Wu, G., et al. 2005. Stepwise engineering to produce high yields of very long-chain polyunsaturated fatty acids in plants. *Nature Biotechnology* 23:1013-1017.

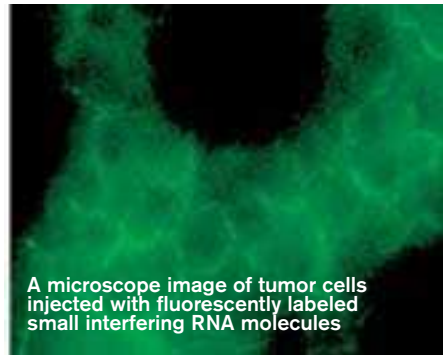
Targeting RNA

Small RNA molecules home in on cancer cells

RESULTS: In a step toward enlisting small interfering RNA molecules (siRNAs) as drugs that turn off specific disease-causing genes, researchers from Harvard Medical School have for the first time induced siRNAs to enter only targeted cells in lab animals. They tagged the siRNAs with an antibody fragment that binds specifically to a cell-surface receptor. In one lab-dish experiment, they found that their tagged siRNAs were absorbed only by mouse melanoma cells engineered to carry this receptor and not by normal melanoma cells. Next, they injected the siRNAs—designed to shut down known cancer-causing genes—into mice that had had the engineered melanoma cells implanted in them. They found that after nine days the tumors were about half the weight of those in control-group mice.

WHY IT MATTERS: By turning off certain genes in a process called RNA interference, small interfering RNA molecules could become a new class of drugs for a wide range of diseases, such as cancer, cystic fibrosis, and certain infectious illnesses. So far, the biggest research challenges have been delivering these fragile molecules throughout the body in a stable form and ensuring that they home in on specific cells. While other researchers had stabilized siRNAs so that they remained intact in the bloodstream of lab animals, the Harvard researchers, led by Judy Lieberman, have taken the next big step: shuttling the molecules to specific cells.

METHODS: In one set of experiments, the researchers engineered mouse melanoma cells to produce a receptor normally found on the surface of the HIV virus. They used this receptor because an antibody tag specific to it had already been shown to deliver DNA to HIV-infected cells, and they wanted to see if the same tag would also work with siRNAs. They fused a fragment of an antibody specific to that receptor to another protein, which they then bound to three different siRNA molecules, each of which shut down a different cancer gene. They introduced the antibody-tagged siRNA molecules, alone and in combination, into lab dishes containing the engineered melanoma cells and measured the effect on cell division. Then they implanted the cancer cells in the flanks of mice, under the skin; injected the mice with the siRNAs; and measured the effects on tumor volume and weight.



A microscope image of tumor cells injected with fluorescently labeled small interfering RNA molecules

NEXT STEP: The researchers need to show that they can target siRNAs to receptors naturally present on tumor cells. And they need to check that their siRNA molecules don't elicit undesirable inflammatory responses in lab animals and are not rapidly degraded by blood enzymes. **Corie Lok**

Source: Song, E., et al. 2005. Antibody mediated *in vivo* delivery of small interfering RNAs via cell-surface receptors. *Nature Biotechnology* 23:709–717.

NANOTECHNOLOGY

Liquid Transistor

Voltage controls fluid transport through nanochannels

RESULTS: University of California, Berkeley, researchers have developed a nanoscale silicon device that acts like a transistor for fluids. By applying a voltage across the device, the researchers stopped and started the flow and controlled the concentration of ions and molecules moving through the device's 35-nanometer-high, one-micrometer-wide channels. In one experiment, the team, led by Arun Majumdar and Peidong Yang, increased the concentration of a dye solution two-fold by applying a positive 50 volts across electrodes that intersected the channels.

WHY IT MATTERS: One potential application of nanotechnology is diagnostics and sensors that manipulate tiny volumes of liquid to detect and measure very low levels of specific molecules. Such "nanofluidics" need a component that controls the movement of liquids and molecules. The Berkeley device could serve that purpose.

Most other nanofluidic devices allow only the passive movement of ions or molecules. This device permits greater control over the fluid's flow and composition. And because nanofluidic circuits could be made using the same techniques that produce electronic circuits, both can be placed on silicon, making possible the electronic control of chemical processing on a chip.

METHODS: The Berkeley team made its device using optical lithography. The nanochannels were connected to three electrodes—one on each end and one, the gate electrode, spanning and intersecting the nanochannels. The researchers introduced a negatively charged dye into the channels and controlled its transport by applying a positive voltage to the gate electrode. The applied positive charge pulled more of the negatively charged dye ions through the channels, increasing their concentration. The researchers measured the effect of the applied voltage on the dye solution by measuring the change in its fluorescence and from that deducing the change in concentration.

NEXT STEP: The researchers are making nanochannels lined on the inside with receptors for specific biomolecules and using the transistors to build nanofluidic circuits that analyze complex mixtures of biomolecules for potential diagnostic and sensing applications. **Corie Lok**

Source: Karnik, R., et al. 2005. Electrostatic control of ions and molecules in nanofluidic transistors. *Nano Letters* 5:943–948.

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- Technology Migration
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2-3 November

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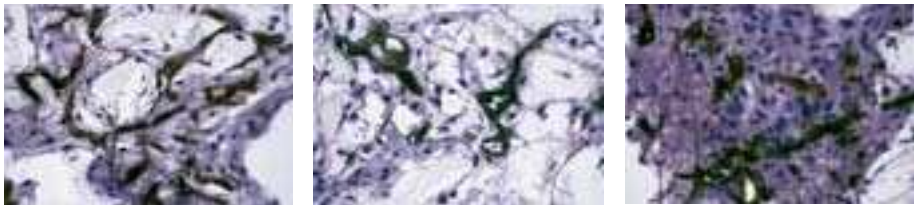


Engineered muscle tissue after two weeks of growth on polymer scaffolds: the brown staining shows new blood vessels.

Engineering Tissue with Blood Vessels

Lab-grown muscle gets nourishment

RESULTS: Researchers in Robert Langer's lab have coaxed skeletal-muscle tissue growing in a lab dish to develop its own network of blood vessels. When the researchers inserted the small piece of tissue into the abdominal muscle of a mouse, they found that 41 percent of the engineered tissue's blood vessels connected with the mouse's vascular system. After two weeks, twice as much of the engineered vascularized tissue survived as did control tissue without blood vessels.

WHY IT MATTERS: One of the biggest problems in tissue engineering is keeping cells alive after they've been implanted in the body. Researchers have had success implanting very thin layers of engineered tissue like skin, because they can use blood vessels from underlying tissue to deliver oxygen and nutrients and get rid of waste. Thicker engineered tissues like muscle, however, tend not to live long because they lack their own sets of vessels that deliver nourishment. Langer and his colleagues have taken an important step toward solving this problem: for the first time, they have gotten blood vessels to grow in a patch of engineered tissue before implanting it in the body. While the researchers focused on muscle tissue, a similar approach could work for other tissues that have a lot of blood vessels, such as liver or heart tissue.

METHODS: Langer and his colleagues grew vascularized muscle tissue on a biodegradable polymer scaffold, which measured 25 square millimeters by one millimeter thick, by seeding it with three different types of cells: mouse muscle stem cells; human endothelial cells, which form blood vessels; and mouse fibroblasts, which give rise to connective tissue and smooth-muscle cells (the researchers hypothesized that these cells would stabilize the vessels). The researchers let the cells grow for several weeks. In one experiment, they removed part of a mouse's abdominal muscle and replaced it with the tissue-covered scaffold. After two weeks, they removed the tissue and analyzed it. **Lisa Scanlon**

Source: Levenberg, S., et al. 2005. Engineered vascularized skeletal muscle tissue. *Nature Biotechnology* 23:879–884.

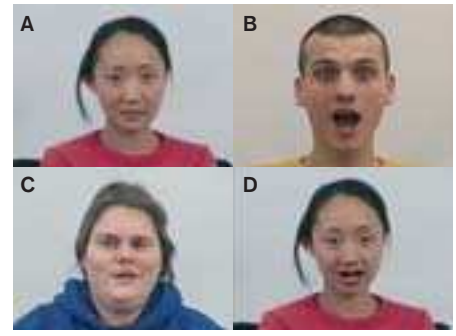
Virtual Expressions

Computer graphics technique transfers facial expressions

RESULTS: Researchers from MIT and Mitsubishi Electric Research Laboratories have created a computer model that allows them to capture from video the facial expression, speech-related mouth shapes, and other key identifying features of one person's face and digitally transfer a select combination of those attributes to video of another person's face. In one example, the researchers took a surprised look from one person and the mouth position from a second person and placed those two features on the face of a third person filmed with a blank expression; in the resulting image, she looked surprised.

WHY IT MATTERS: Making digital facial movements look natural is a major challenge in computer animation. These new tools could be used to give computer-generated characters in films and video games more-realistic faces, based on the movements made by live actors. Existing techniques, such as those used in movies like *The Polar Express*, typically capture the motion of a live actor using reflective markers stuck to the actor's body and face. The MIT method can capture motion and expressions from a video recording of the actor without the need for markers, making this kind of computer animation potentially simpler and cheaper.

METHODS: Daniel Vlasic of MIT and his colleagues created their model using data from 3-D scans of 31 subjects making different facial expressions and mouthing different sounds. They then filmed subjects performing—singing, for instance. They tracked the facial movements of the subjects and fed that data into the model. The model used that data to change the expressions or mouth movements of a second person, and the researchers imposed those changes on video of the person. The model allowed the researchers to manipulate a subject's attributes, such as a smile or identifying features, independently of one another, so that they could transfer, say, a smile to a person without changing that person's identity. **Corie Lok**



A computer graphics technique combines the surprised look from B with the articulation of the mouth in C and superimposes them on A, resulting in D.

Source: Vlasic, D., et al. 2005. Face transfer with multilinear models. *ACM Transactions on Graphics* 24:426–433.

COURTESY OF DANIEL VLASIC (PORTRAITS); SHULAMIT LEVENBERG (MUSCLE TISSUE)

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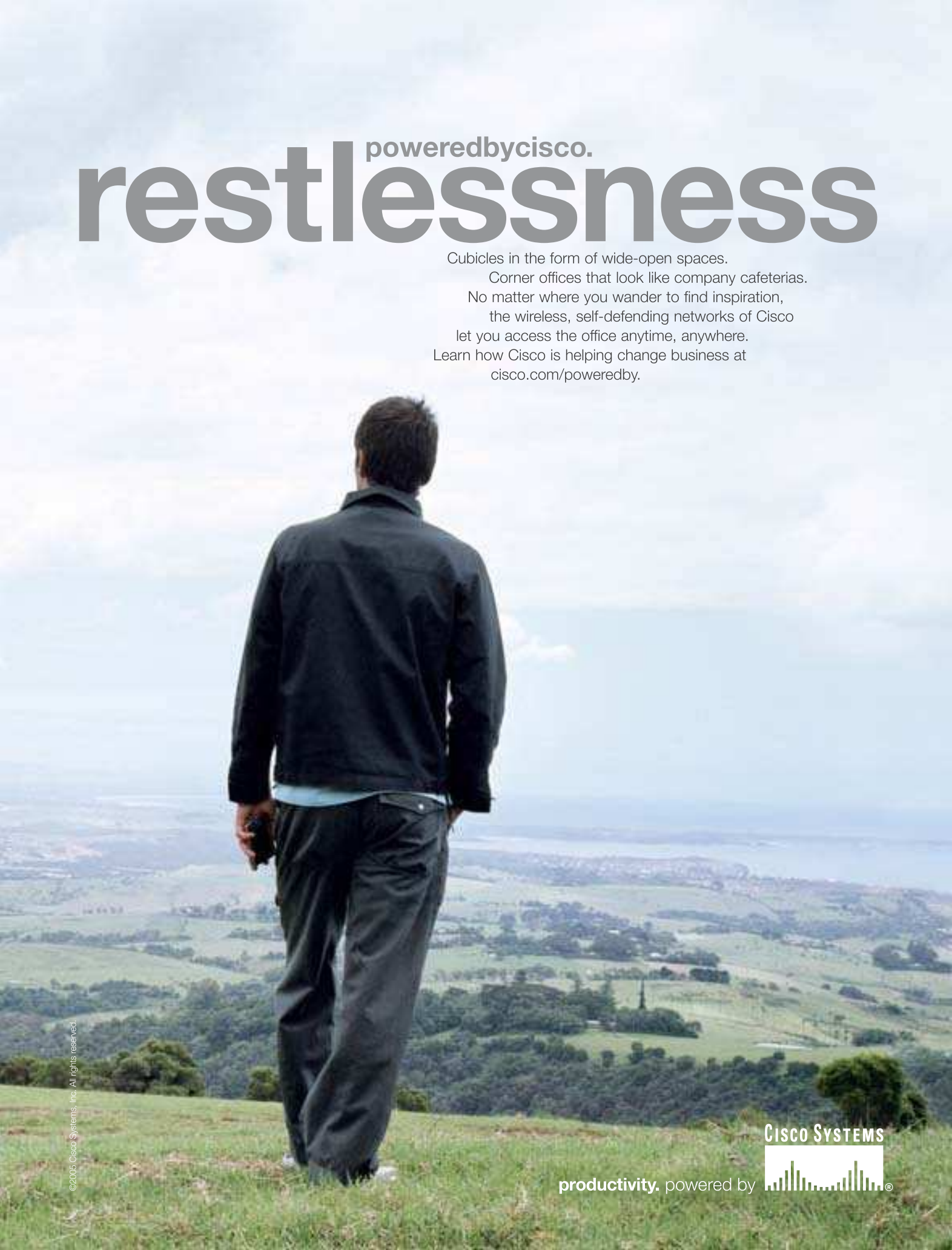

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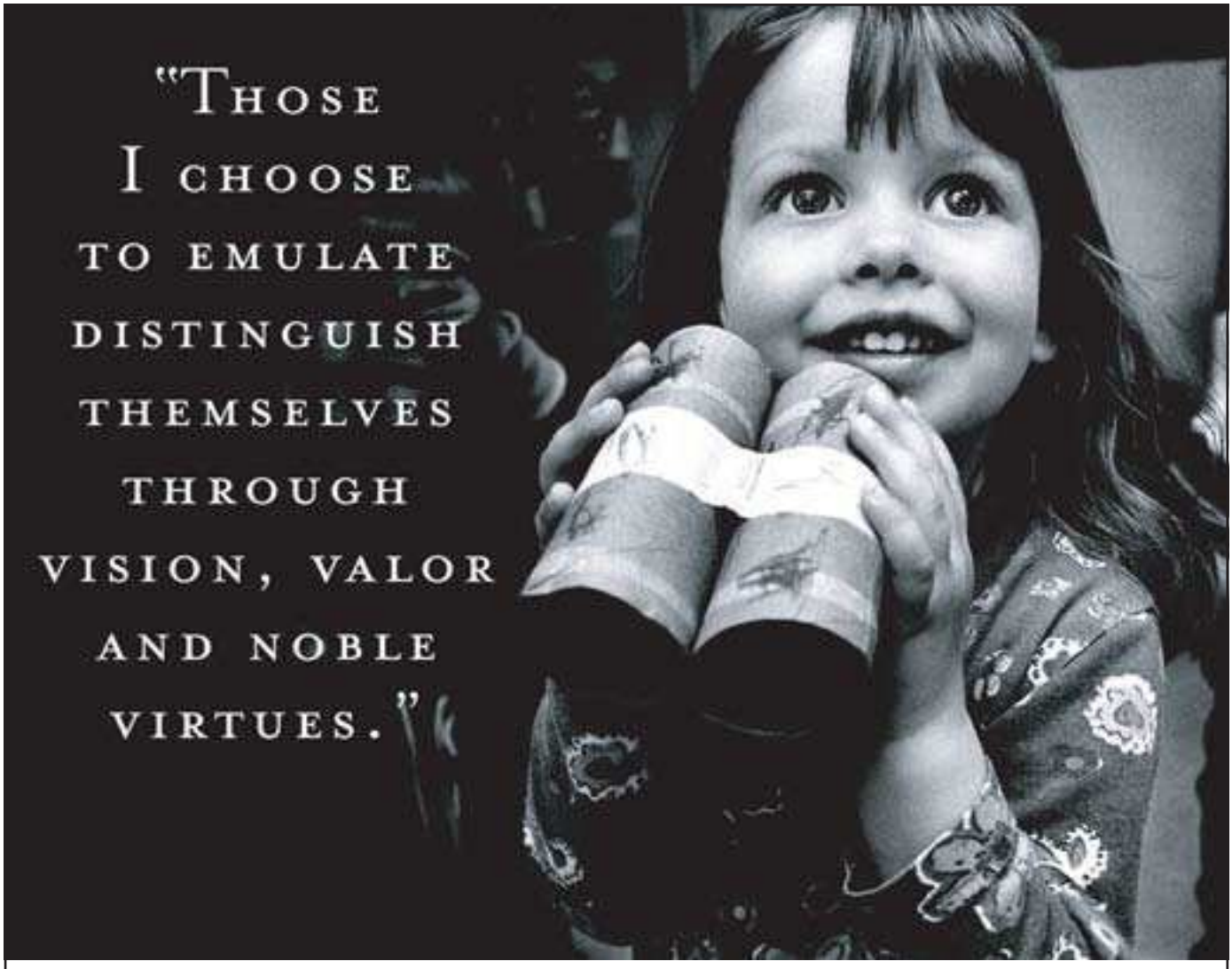

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